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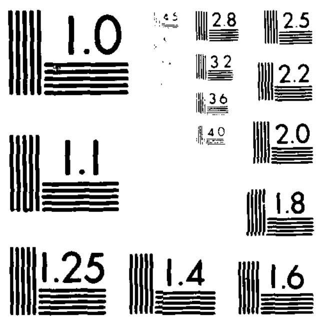


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# COMPARISON OF THE CLIMATES OF SELECTED LOCATIONS IN THE UNITED STATES WITH THE CLIMATE OF BEERSHEBA, ISRAEL

FINAL REPORT

JANUARY 1981



PREPARED BY

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FOR

US ARMY ATMOSPHERIC SCIENCES LABORATORY
WHITE SANDS MISSILE RANGE, NEW MEXICO 88002

AND

BATTELLE COLUMBUS LABORATORIES
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DURHAM, NORTH CAROLINA 27707

UNDER CONTRACT DAAG29-76-D-0100

CONTRACT MONITORS: BRUCE W. KENNEDY & DONALD SNIDER

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|---|---|
| 1. REPORT NUMBER: ASL-CR-81-0100-2 — 2. GOVT ACCESSION NO.: AD-A097529 | 3. RECIPIENT'S CATALOG NUMBER |
| 4. TITLE (and Subtitle): COMPARISON OF THE CLIMATES OF SELECTED LOCATIONS IN THE UNITED STATES WITH THE CLIMATE OF BEERSHEBA, ISRAEL. | 5. TYPE OF REPORT & PERIOD COVERED: Final Report. |
| | 6. PERFORMING ORG. REPORT NUMBER |
| 7. AUTHOR(s): Claude E. Duchon | 8. CONTRACT OR GRANT NUMBER(s): DAAG29-76-D-0100 |
| 9. PERFORMING ORGANIZATION NAME AND ADDRESS: University of Oklahoma, Norman, Oklahoma 73069 | 10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: DA Task 1L162111AH71 |
| 11. CONTROLLING OFFICE NAME AND ADDRESS: US Army Electronics Research and Development Command, Adelphi, MD 20783 | 12. REPORT DATE: JANUARY 1981 |
| | 13. NUMBER OF PAGES: 186 |
| 14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office): US Army Atmospheric Sciences Laboratory, White Sands Missile Range, NM 88002 | 15. SECURITY CLASS. (of this report): UNCLASSIFIED |
| (12) 173 | 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE |

16. DISTRIBUTION STATEMENT (of this Report)

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17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

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19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

| | |
|---|---|
| Climatology | Meteorology |
| Electro-optics | Obscuration |
| US-Israel | |

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A comparison has been made of the climates of Daggett, California; El Paso, Texas; Fort Huachuca, Arizona; and Yuma, Arizona, with the climate of Beersheba, Israel, located in the northern Negev. The purpose of the study was to find a location in the US near an Army installation that has a climate similar to Beersheba. Based on a preliminary climate assessment, the above four stations were selected for an in-depth analysis along with Beersheba.

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20. ABSTRACT (cont)

Thirteen variables were chosen for the comparison study. Among them are temperature, moisture, wind, cloud related variables, visibility and atmospheric stability. The main method of comparison was the plotting of 3-hourly means by month, monthly means and frequencies of occurrence. Each plot contains means or frequencies for Beersheba and one of the US stations.

One outstanding feature of the climate of Beersheba is the large amplitude of the diurnal cycle of many of the meteorological variables. No US station exhibits this feature. Another notable feature is the frequent occurrence of fog and haze at Beersheba, in contrast to the US stations. Based on the many comparisons made, none of the above US stations provides a good model for Beersheba. Moreover, it seems unlikely that any location in the US would be a good candidate. On the other hand, the US stations examined appear promising as models for the central and southern Negev, where the climate is representative of large areas in the Middle East.

## PREFACE

The USA Atmospheric Sciences Laboratory has been involved in an extensive program to investigate dust obscuration at visible, infrared, and millimeter wavelengths. One goal is to develop and validate models to quantitatively describe obscuration using inputs which are available from the climatology and soils data bases.

The following report is an initial attempt to look at the types of climate information that are readily available on a worldwide basis and to see how the information might be used to extrapolate the ASL dust obscuration modeling. The initial decision was to look at those geographic regions which may be of political or military interest for which dust obscuration may be important in military operations. Israel has climate regions which are felt to be representative of the Mideast. Since Israel has studied its climate extensively, we decided to focus initially on meteorological parameters in Israel and to compare them to those within the Continental United States (CONUS). To further narrow the study we decided to limit the comparisons to military bases in CONUS, since most large-scale obscuration tests would probably be limited to CONUS military bases.

Four bases--Fort Irwin, Fort Huachuca, Yuma Proving Ground, and White Sands Missile Range--were initially selected as being representative of desert environments, and climates were studied in detail for these comparisons.

Several general comments should be made on the types and potential uses of the climate data bases. Climatology data bases by their very nature consist of data averaged over long time spans, whereas detailed obscuration modeling looks at specific events of generally short duration. Thus, most climatological variables are not direct inputs into dust or smoke obscuration models (as opposed to general visibility or weather obscuration models). However, climatology data bases do serve to define the classes and ranges of meteorological inputs which need to be considered.

The general climatological divisions found in the southern part of Israel are representative of the Mideast. Similar conditions of aridity and general climate can be found in the southwestern desert of the United States. Certain differences should be noted however. In general, the areas studied in Israel show a winter rainfall maximum, whereas the Southwestern United States generally experiences a summer rainfall maximum. Thus, those properties which are soil moisture dependent should be compared on a summer-winter basis between the CONUS and Mideast sites. Many sites in southern Israel also experience a morning dew which may affect soil surface properties and subsequent obscuration during the early morning hours; this occurrence is not generally

found in the Southwestern United States. It should be kept in mind that meteorological inputs into dust and smoke obscuration models are site and event dependent.

In summary, we believe that both the southern part of Israel and the Southwest CONUS are generally representative of a Mideast environment in terms of dust obscuration. Israel is a highly variable country with a variety of climates, all of which are generally found within the CONUS, but not necessarily found in the four sites selected for this study, which was aimed primarily at arid environments. Those differences between CONUS and Israeli climates (and their effects on battlefield obscuration) are believed to be small compared to the seasonal and spatial variation which exists within Israel itself. Put in other terms, differences in obscuration between a test conducted in Israel and one conducted in an appropriately selected CONUS site are expected to be smaller than differences between two tests conducted in Israel at the same site six months apart or two tests conducted at the same time in different climate regions of Israel.

A comparison report, Soils of Israel and Their Similarity to Soils of the United States, by LeRoy A. Daugherty, describes a comparison of soil types between Israel and the specified locations in the United States.

The author wishes to thank Pat Avara of the Atmospheric Sciences Laboratory, WSMR, for his expeditious effort in preparing a Beersheba magnetic tape that could be easily read on the IBM 370. Phil McDonald did an excellent job in programming, and his continuous availability and project support are very much appreciated. The fine manuscript typing was done by Nancy Masud. Her willingness to work at odd times on little notice was a great help.

## Table of Contents

# I. INTRODUCTION

Battlefield obscuration plays an important role in the performance of Army electro-optical devices. In turn, the type, magnitude and frequency of obscuration depends on the climatology of the battlefield area. Since it is not usually possible to field test electro-optical devices in foreign countries, where the battles may occur, it is necessary to find locations in the U.S. that are climatologically similar to potential foreign battlefield areas.

The objective of this research is to identify locations in the U.S. that have a climatology similar to the Beersheba, Israel area. Preferably, these locations would be near existing military test facilities.

The first step taken to accomplish this objective was to determine the climate of the Beersheba region. This was done using extant climatological tabulations. From this investigation emerged a picture of a hot and dry climate. On this account the southwestern U.S. was the logical region from which to select stations for comparison. Since there are a number of military sites in this region the second step was to obtain meteorological data for stations at or near these sites. Magnetic tapes for seven stations in the Southwest were purchased from the National Climate Center, Asheville, North Carolina. Of the seven stations four were chosen for analysis, namely, Daggett, California (near Ft. Irwin),

El Paso, Texas (near White Sands Missile Range), Ft. Huachuca, Arizona, and Yuma, Arizona (near Yuma Proving Ground).

The third step was to analyze the data from the above four stations and Beersheba. The Beersheba data were obtained on a magnetic tape provided by the Atmospheric Sciences Laboratory, WSMR. Programs were written for the University of Oklahoma IBM 370/158 computer to process the data tapes, perform various statistical analyses and plot the results using a drum plotter.

The variables that will be discussed in the main body of this report are dry-bulb temperature, dew-point temperature, relative humidity, wind speed, stability, visibility, total sky cover and present weather. These are the variables of primary interest. The variables of secondary interest are wind direction, absolute humidity, ceiling height, lowest cloud layer and sea-level pressure; these are discussed in Appendix A.

The principal statistical method employed in comparing the climatology of the U.S. stations with the climatology of Beersheba is the use of plots showing 3-hourly means by month and monthly means for some variables and frequencies of occurrence by class of the other variables. Each plot shows the results for Beersheba and one of the U.S. stations. These plots are presented in Section V and Appendix A. Three-hourly and daily standard deviations by month of the former set of variables are given in Appendix B.

## II. THE CLIMATE OF BEERSHEBA

### A. Köppen Classification

A common climate classification scheme used by geographers is that developed by Köppen and first published in 1901 [1, p. 242]. Accordingly, Beersheba is classified as BShs. The letter B means a dry climate, i.e., there is an excess of evaporation over precipitation. Streams cannot originate in a B climate and there is no surplus water.

Given that the first letter is B, the second letter is either W or S. W indicates desert and S indicates steppe (a dry grassland). The boundary between BS and BW climates depends on the annual distribution of rainfall and the annual temperature. Using a mean annual temperature of 18.8C (66F) and the fact that winters are wet and summers are dry, as seen in Table 1, yield a boundary value in rainfall of 190 mm (7.5 in) versus an annual rainfall of about 208 mm (8.2 in) [2]; thus Beersheba is barely a steppe climate. Fig. 1 shows the annual rainfall south of 32°N [3]. The northern Negev, in which Beersheba is located, is semiarid and the southern Negev is desert. Negev means "dry".

The letter h (k) indicates the annual temperature is greater (less) than 18C (64.4F) and s indicates a summer drought, i.e., the rainfall in the wettest winter month is more than three times the rain in the driest summer month. Fig. 2 summarizes the climate of Israel south of 32°N. The

Table 1. Mean monthly precipitation in mm for the various stations. Beersheba data based on 3611 observations. Daggett is based on 24 years, El Paso 30 years, Ft. Huachuca 22 years, Yuma 30 years; these data from the National Climate Center.

| Station | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Ann |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Beersheba | 37 | 42 | 37 | 12 | 2 | 1 | 0 | 0 | 0 | 2 | 29 | 45 | 208 |
| Daggett | 11 | 7 | 7 | 7 | 2 | 2 | 8 | 13 | 10 | 5 | 9 | 10 | 92 |
| El Paso | 10 | 11 | 10 | 6 | 8 | 15 | 39 | 28 | 29 | 20 | 8 | 13 | 197 |
| Ft. Huachuca | 35 | 33 | 16 | 7 | 9 | 17 | 94 | 100 | 33 | 17 | 26 | 30 | 418 |
| Yuma | 10 | 7 | 5 | 3 | 1 | 0 | 5 | 11 | 6 | 7 | 6 | 9 | 68 |

Csa climate is subtropical with hot and dry summers. It is noteworthy that BW climates are far more representative of the Middle East that includes Libya, Egypt, Saudi Arabia, and Iraq than BS climates.

B. Synoptic Features

During the cool season (November-April) the most common surface wind direction is east (45°-135°) as a result of the outflow from the large anticyclones over interior Eurasia [4, p. 244]. The next most common direction is west in association with the passage of cyclonic disturbances (middle latitude cyclones). The region around Beersheba is affected by about 28 cyclones annually with an average of 1 during the summer months (June-August) [5, p. 31ff]. These develop mainly in the western Mediterranean area with their low-pressure centers tracking eastward guided by the westerly winds in the middle and upper troposphere. In the eastern Mediterranean the centers curve northeastward to the west and northwest of

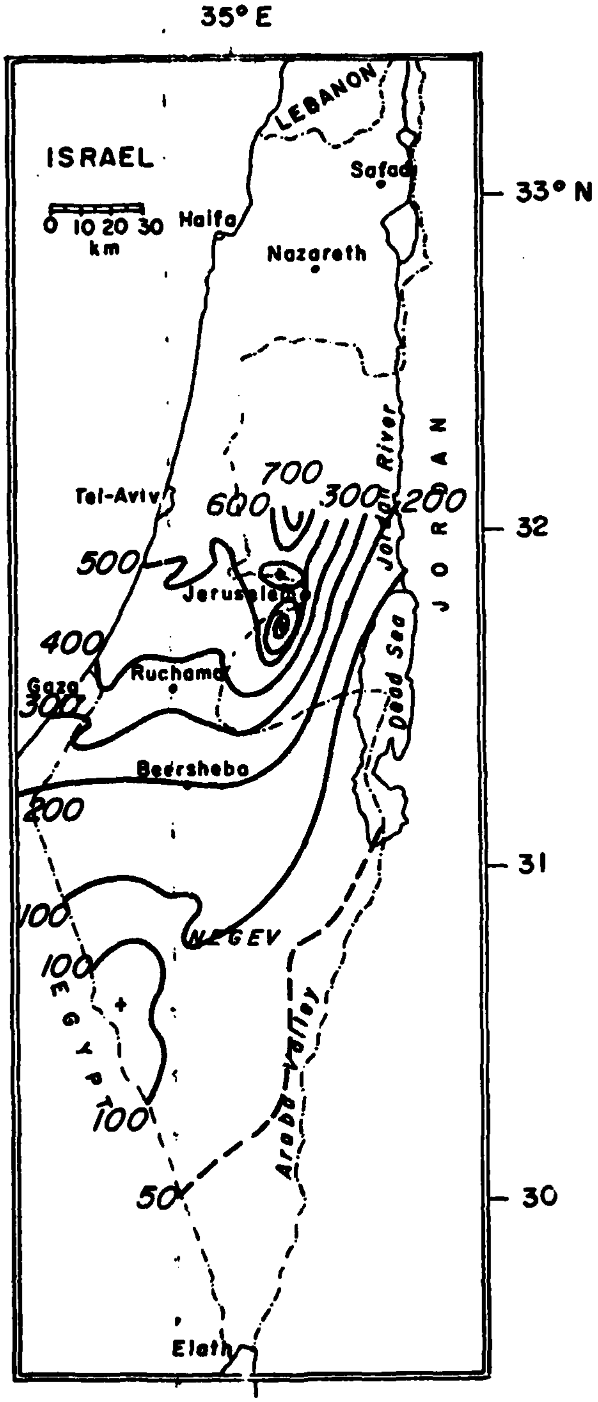



Fig. 1. Annual rainfall in mm for central and southern Israel [3].

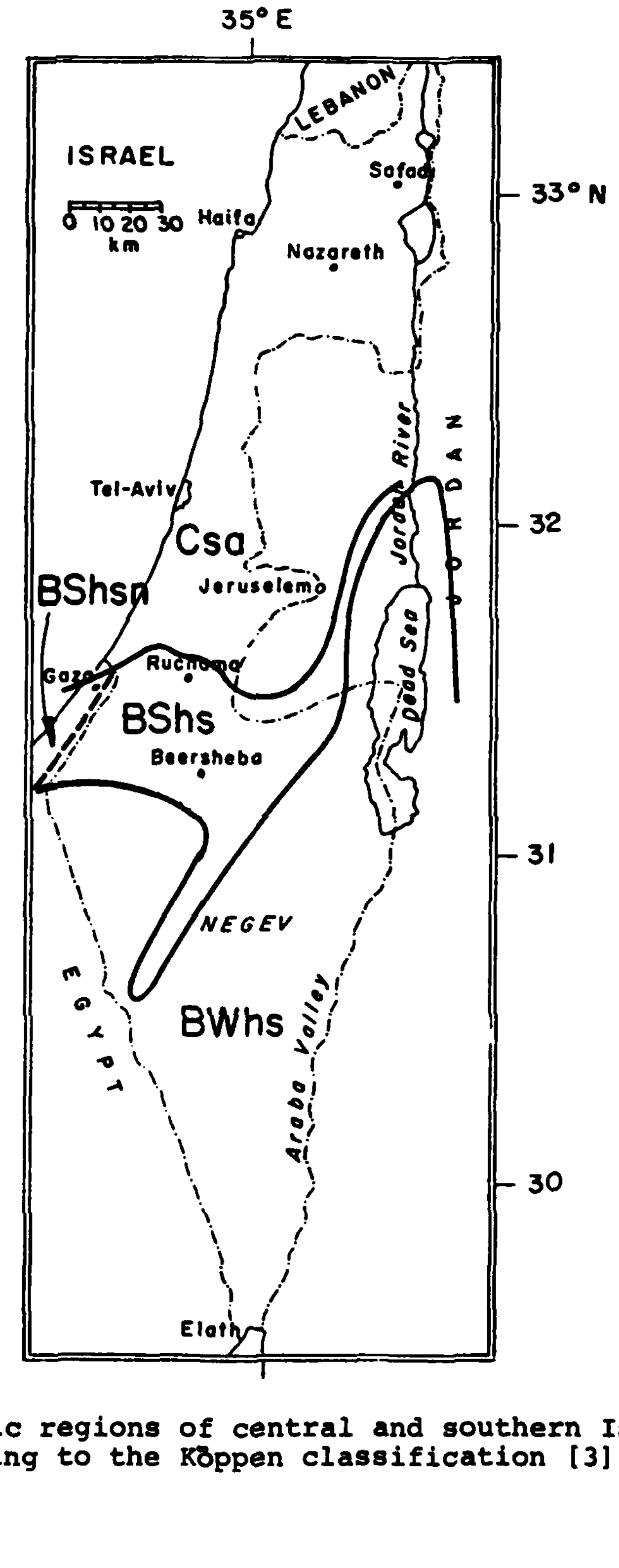



Fig. 2. Climatic regions of central and southern Israel according to the Köppen classification [3].

Israel. In spite of the fact that most of the cold fronts associated with the cyclones are rainless [6], they provide most of the cool season precipitation at Beersheba and all of Israel. Because of these storm tracks Israel and the surrounding area is the most extensive of the earth's dry areas with a winter maximum of rainfall (BSh(k)s; BWh(k)s [4, p. 246].

During the summer months the most common surface wind direction is west in association with outflow from the Azores anticyclone [4, p. 246]. Although there is plentiful water vapor in the lower troposphere there is practically no rainfall because of a middle and upper level troposphere anticyclone extending across northern Africa, Saudi Arabia and eastward. The descending air serves to inhibit the convection needed for precipitation to occur.

C. Other Features

Dew is a common occurrence in the Beersheba area. Measurements from 1945-1952 show 50-60 nights of dew during the summer months, 30-40 during the winter months and 160-200 annually [3]. It is considered to be so important in the northern and western Negev that one climatologist suggests this area have an additional climatic subtype [7].

Another significant feature is the sand or duststorm. A duststorm is reported when the visibility due to dust is reduced to or below 1 km at the time of observation. Based on a study by Katsnelson [6] most duststorms in the Northern

Negev (in which Beersheba is located) are associated with the passage of cold fronts moving from west to east. About 60% of the duststorms occur from the SW-NW (210-330°) with wind speeds ranging from 3.5 to 17 $ms^{-1}$, the most frequent speed being around 12 $ms^{-1}$. The most common time for duststorms to occur is at 1400 (IST) with comparatively few occurring during the nighttime hours. March is the month of most frequent occurrence of duststorms and none occur during July and August.

The number of duststorms observed over the 11 year period of his study was 39 as reported at 3-hourly intervals. The total days with duststorms was 27. If the visibility criterion were relaxed to 5 km visibility the statistics cited earlier would be the same, but the number of cases would increase to 88 and the total days with duststorms would increase to 58.

D. Topography

Fig. 3 shows the general topography of Israel south of 32°N. In general the elevation increases from the Mediterranean Sea eastward to a line from Jerusalem southward then southwestward. East of the line the elevation drops to sea level and below. The peak elevation is 1020 m at a point (Mt. Hebron) 28 km SSW of Jerusalem.

If a normal were drawn from the Mediterranean coast to Beersheba there would be a gradual rise in elevation to 290 m at Beersheba. The city is in a broad valley that opens to the west. The topography to the east of the city is more

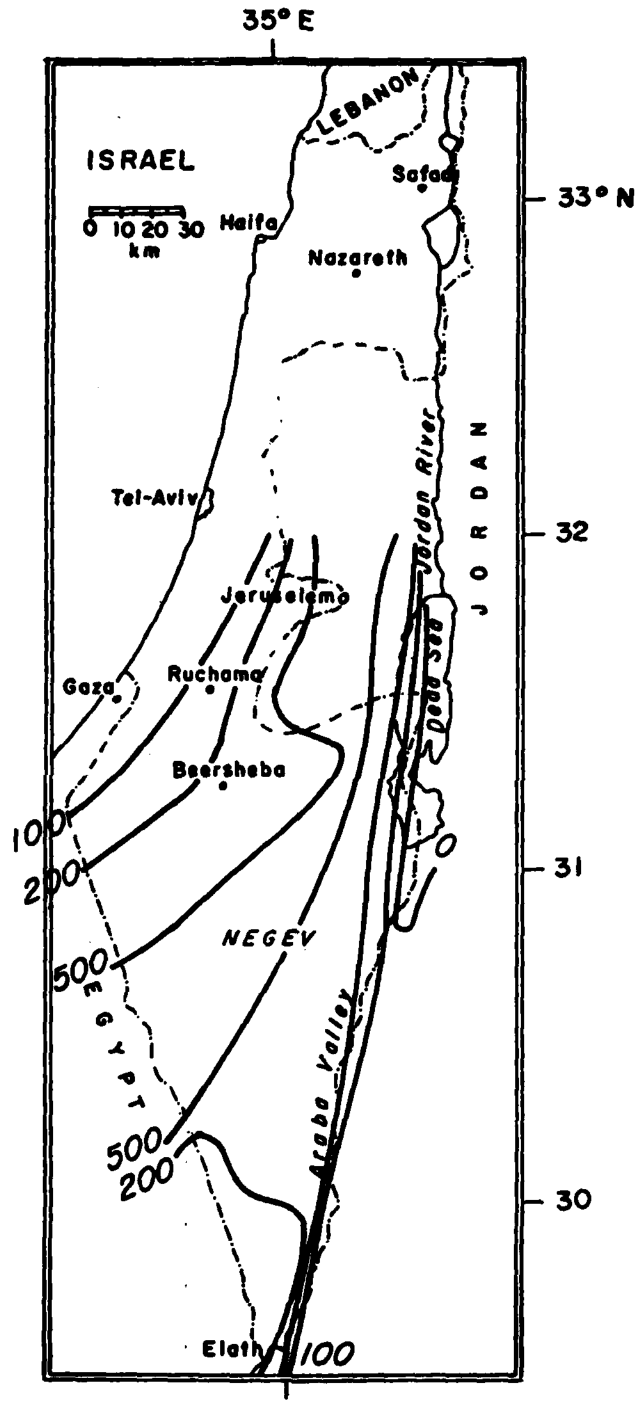



Fig. 3. Elevation in meters for central and southern Israel.

rugged. Along a line from Beersheba to the Dead Sea the elevation reaches a maximum about midway where the elevation drops sharply to the Dead Sea (-396 m).

## III. THE SELECTION OF U.S. STATIONS AND DISCUSSION OF THEIR CLIMATES

### A. Selection

Fig. 4 shows the B climates of the U.S. As expected they are located in the western third of the U.S. mostly in the lee of the west coast mountain ranges and the Rocky Mountain area and to the west of the Gulf of Mexico, the main source of moisture for the eastern two-thirds of the U.S. The slashed area represents climates other than B. The boundary between BS and BW passes through Nevada, Utah, Arizona, New Mexico, Texas, and into Mexico.

At first glance it may seem odd that stations with the classification BW were chosen (Ft. Huachuca lies on the boundary between W and S). In the first place there are no stations in the northern half of the western U.S. that have nearly as high an average annual temperature as Beersheba. In the second place nowhere in the BS region is there the strong winter maximum-summer minimum in rainfall as at Beersheba. In view of these facts and in consideration of their proximity to military installations, Daggett, Yuma, Ft. Huachuca and El Paso appeared to be reasonable choices. The discussion of the climate of each station that follows is based on numerical and narrative climatological summaries obtained from the National Climate Center, atlases and personal experience.

### B. Daggett, California (elevation 585 m)

Daggett is located in the Mojave Desert about 55 km southwest of Fort Irwin. About 65 km to the south are the

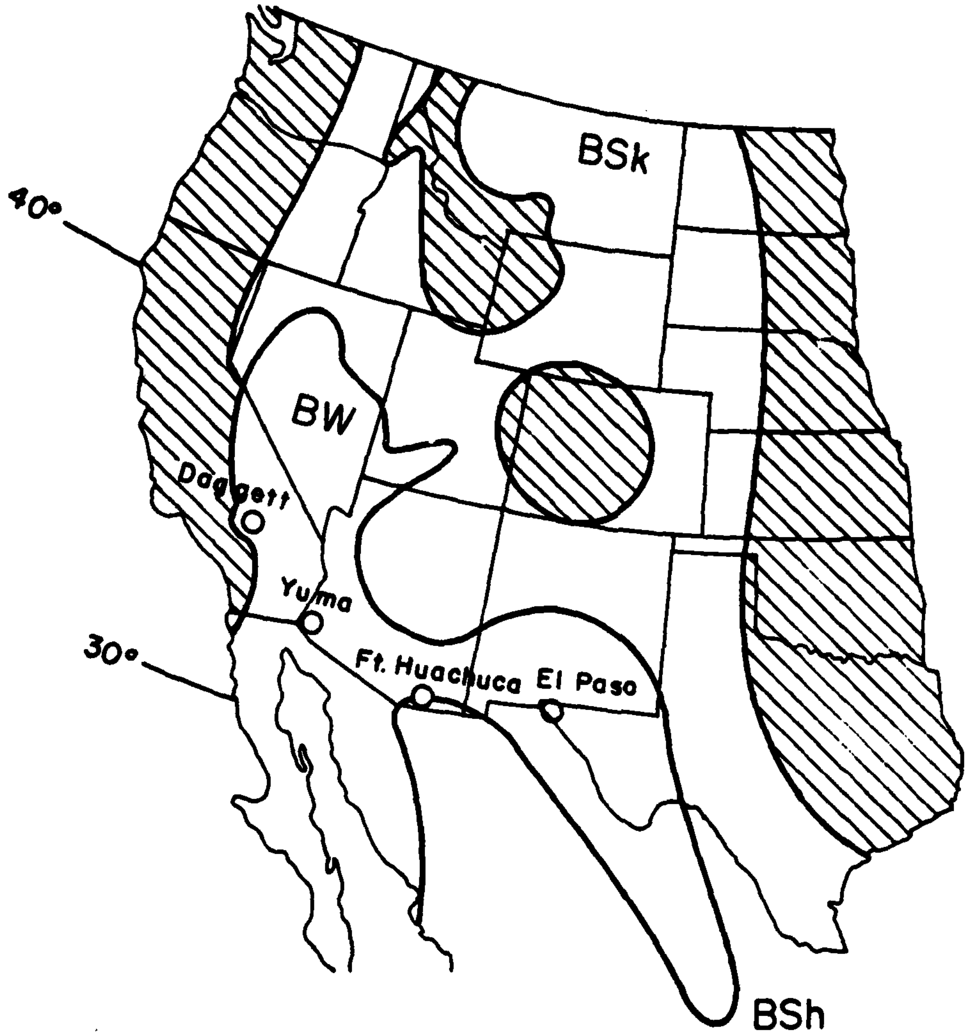



Fig. 4. The B climates of the United States.

San Bernardino Mountains with the San Gabriel Mountains further to the southwest. The Tehachapi Mountains are 150 km to the west forming the south end of the Sierra Nevada, which extend northward. The area around Daggett contains numerous playas ("dry lakes") and volcano plugs with their alluvial fans. The creosote bush is a common element of the vegetation.

During the hottest month of the year (July) the average daily maximum is just under 40C (104F). During the coldest month (January) the average minimum temperature is 2C (36F). Annual precipitation is low, less than 100 mm (4 in) as shown in Table 1. The precipitation is relatively uniform throughout the year except for May and June when, more often than not, there will be no rain or only a trace. This is due to the influence of the North Pacific high in which subsidence (descending air) effectively caps the deep convection needed for precipitation.

Measurable snowfall occurs in one out of 5 winter seasons. In December of 1967 330 mm (13 in) of snow fell.

C. El Paso, Texas (elevation 1190 m)

The climate of the region is characterized by abundant sunshine throughout the year, high but no extreme (except for 1980) daytime temperatures, low humidity, little rainfall and mild winters. Rainfall is sufficient only for desert vegetation so that crops, gardens, and lawns require irrigation. Dry periods of several months' duration without appreciable rainfall are not unusual. Almost half of the annual

precipitation occurs in the three-month period, July-September, from brief, but at times heavy, thunderstorms. Small amounts of snow fall nearly every winter, but snow cover seldom remains on the ground for more than a few hours.

Daytime summer temperatures are frequently above 32C (90F) but seldom over 38C (100F). Minimum summer nighttime temperatures are around 20C (68F). Winter daytime temperatures rise to 12C (54F) to 15C (59F) on the average. At night they drop below freezing about 50% of the time in December and January. The low afternoon relative humidity (10-15% in April-June, 25-30% in July-September) during the warm months aids the efficiency of evaporative coolers, which are widely used.

Prevailing winds are from the west and north in winter and the east and south in summer. The Franklin Mountains begin within the city and extend northward for about 25 km; the mountain peaks range from 1430 m to 2180 m msl. They contribute to the gustiness of wind during high wind speeds, and cause changes in direction during periods of light winds.

A tabulation of "duststorms", for a period of 20 years, shows that they are most frequent in March and April and rare in July through December. The highest monthly average is in March - nearly 40 hours a month with visibility reduced to 10 km or less. While wind speeds are not excessively high, the soil surface is dry and loose and natural vegetation is sparse, so moderately strong winds raise considerable dust and sand.

D. Ft. Huachuca, Arizona (elevation 1420 m)

Ft. Huachuca is located on the northeast slopes of the Huachuca Mountains in southeastern Arizona, 25 km north of the Mexican border. The surrounding area is dotted with a series of minor mountain ranges, the adjoining Huachucas, the Santa Ritas, 50 km to the northwest, the Whetstones 30 km to the north and the Mules, 45 km to the east. The highest peak in the Huachucas is 2880 m. Several peaks south of the border exceed 2400 m. The San Pedros Valley, which runs from the SSW to the NNW is centered 22 km east of Ft. Huachuca. Mesquite grass is the prevailing type of vegetation on the valley floor but at high elevations chaparral and oak woodland are more common. Above 2000 m stands of yellow pine can be observed.

The two dominating features of the climate of Ft. Huachuca are its abundant rainfall and mild temperature throughout the year. Ft. Huachuca is in a perfect position to get a maximum amount of rain from the moist tropical air masses which move into the area in the summer from the east and southeast. Under the combined influence of strong surface heating and orographic uplift of the air over the Huachuca Mountains, numerous showers and thunderstorms often develop in the vicinity during the warmer hours of the day. Although the showers are brief they are intense enough and frequent enough to account for about 50% of the annual precipitation.

Most of the remainder of the rain occurs during the colder months in association with middle-latitude cyclones that

move into the state from over the Pacific Ocean. The intensity and frequency of these storms vary greatly from one year to the next, so that winter precipitation is normally much above or much below the long-term average value, usually the latter. About 1/10 of the winter precipitation falls as snow which rarely stays on the ground for more than a day or two.

The mildness of winter temperatures is, in part, due to its position on the slope of the Huachuca Mountains since the coldest and densest air tends to settle on the valley floor. In addition, there is usually ample sunshine. As a result midday temperatures rise to around 15C (59F) and sometimes to 25C (77F). In summer the high elevation and frequent cloudiness combine to keep the maximum temperature down. Summer nights are clear and cool, the minimum temperature around 15C (59F).

E. Yuma, Arizona (elevation 60 m)

The climate of Yuma is indeed that of a desert. The summers are long and hot. The 1941-1970 period of record shows that maximum afternoon temperatures average above 40C (104F) during June, July, and August. The hot air ascends and draws in moist air from the Gulf of California (about 110 km to the south). Consequently, the water content of the air from mid-July to mid-September is higher than might be expected over a desert area. Evaporative coolers are very effective during all months except July, August, and

September, months when the wet-bulb temperatures are between 24C (75F) and 27C (80F).

The reason that showers and thundershowers don't develop with the great surface heating and plentiful moisture is that Yuma, like Daggett, is located on the eastern end of the deep subtropical North Pacific high, which suppresses shower activity. This feature also contributes to Yuma receiving a higher percentage of sunshine than any other U.S. station.

## IV. PREPARATION OF DATA FOR COMPARATIVE ANALYSIS

### A. Station Location and the Determination of Local Mean Solar Time

An important consideration in comparing climatological data among stations on a time scale shorter than one day is the times of the observations in solar time. This is because of the strong influence of the sun on the diurnal variation of many meteorological variables. Even after obtaining the correct time alignment it still would be possible for two stations to differ by as much as $1\frac{1}{2}$ hours in solar time for 3-hourly comparisons.

Table 2 shows the latitude, longitude, time zone, and the correction to be made to each station's observation time to put it in local mean solar time. Regardless of the station location or time zone, the 3-hourly meteorological observations are taken simultaneously, starting at 0000 GMT. Thus Daggett, which is 3°13' east of the standard meridian (120°), has a correction of 3.22°x4 min/° = 13 min. Each row in Table 3 shows one of the eight sets of 3-hourly observation times selected for comparison among the five stations. The observation times are given in the local time and, after applying the correction from Table 2, in local mean solar time. The largest time difference occurs between Beersheba and Daggett, namely, 1 hr 6 min. This should not be significant in the 3-hourly comparisons. The smallest difference between Beersheba and another station is 25 min for Beersheba-El Paso.

Table 2. Station location and time information.

| Station | Latitude(°) | Longitude(°) | Standard Time Zone | Correction to Observation Time (min) |
|---|---|---|---|---|
| Beersheba | 31°14'N | 34°47'E | Israel | +19 |
| Daggett | 34°52'N | 116°47'W | Pacific | +13 |
| Yuma | 32°40'N | 114°36'W | Mountain | -38 |
| Ft. Huachuca | 31°36'N | 110°20'W | Mountain | -21 |
| El Paso | 31°48'N | 106°24'W | Mountain | - 6 |

Table 3. Observation times in local time (LT) and in local mean solar time (LMST).

| Beersheba | | Daggett | | Yuma | | Ft. Huachuca | | El Paso | |
|---|---|---|---|---|---|---|---|---|---|
| LT(IST) | LMST | LT(PST) | LMST | LT(MST) | LMST | LT(MST) | LMST | LT(MST) | LMST |
| 0200 | 0219 | 0100 | 0113 | 0200 | 0122 | 0200 | 0139 | 0200 | 0154 |
| 0500 | 0519 | 0400 | 0413 | 0500 | 0422 | 0500 | 0439 | 0500 | 0454 |
| 0800 | 0819 | 0700 | 0713 | 0800 | 0722 | 0800 | 0739 | 0800 | 0754 |
| 1100 | 1119 | 1000 | 1013 | 1100 | 1022 | 1100 | 1039 | 1100 | 1054 |
| 1400 | 1419 | 1300 | 1313 | 1400 | 1322 | 1400 | 1339 | 1400 | 1354 |
| 1700 | 1719 | 1600 | 1613 | 1700 | 1622 | 1700 | 1639 | 1700 | 1654 |
| 2000 | 2019 | 1900 | 1913 | 2000 | 1922 | 2000 | 1939 | 2000 | 1954 |
| 2300 | 2319 | 2200 | 2213 | 2300 | 2222 | 2300 | 2239 | 2300 | 2254 |

B. Period of Observation

The period of observation for Beersheba is 1 January 1966 to 12 December 1977. While this is a 12 year period about 20% of the observation times are missing. The equivalent period of observation is about 9.6 years. Therefore, in order to compare statistics that have approximately the same level of confidence a 10 year period was analyzed for the four U.S. stations, in which there were, with one exception, practically no missing data.

The period chosen was from 1 January 1961 to 31 December 1970. The reason for this choice was that there were no Ft. Huachuca data readily available from NCC after 1970. In order to provide homogeneous data sets among U.S. stations the same period was analyzed for the other three stations, although data for the Beersheba period of observation were available. The difference in period of observation for the U.S. and Beersheba data sets should be of negligible climatological significance.

C. Statistical Calculations

1. Introduction

Each of the thirteen variables that was analyzed was placed into one of two categories of statistical analysis. One category dealt with means and standard deviations. The other dealt with frequency of occurrence. Those in the former are dry-bulb temperature, dew point, relative humidity, absolute humidity, wind speed, stability index and sea-

level pressure. Those in the latter category are wind direction, total sky cover, visibility, ceiling height, lowest cloud height and current weather.

2. Computation of Means

Four different means were calculated: 3-hourly means by month, monthly means, mean daily maximum by month and mean daily minimum by month. The formula for a 3-hourly mean of variable X at a station is

$$\bar{X}_{mh} = \frac{1}{YD} \sum_{y=1}^{Y} \sum_{d=1}^{D} X_{ymdh}$$

| | | |
|---|---|---|
| where | m | month of interest (Jan, Feb, ...) |
| | h | hour of interest (01, 04, ... or 02, 05... depending on the station) |
| | y | year index |
| | d | day index |
| | Y | number of years of data |
| | D | number of days in month m. |

The formula for a monthly mean of variable X is

$$\bar{X}_{m} = \frac{1}{YDH} \sum_{y=1}^{Y} \sum_{d=1}^{D} \sum_{h=1}^{H} X_{ymdh}$$

where H number of observations in a day.

The formula for the mean daily maximum of variable X for a given month is

$$\bar{X}_m^{max} = \frac{1}{YD}\sum_{y=1}^{Y}\sum_{d=1}^{D} X_{ymd}^{max} .$$

The formula for the mean daily minimum by month is the same as that above except max is replaced by min.

3. Computation of Standard Deviations

Two different standard deviations were calculated: 3-hourly standard deviations by month and daily standard deviations by month. The formula for a 3-hourly standard deviation of variable X for a selected station is

$$XSD_{mh} = \left[\frac{1}{YD}\sum_{y=1}^{Y}\sum_{d=1}^{D} (X_{ymdh}-\bar{X}_{mh})^2\right]^{1/2} .$$

The formula for a daily standard deviation is

$$XSD_m = \left[\frac{1}{YDH}\sum_{y=1}^{Y}\sum_{d=1}^{D}\sum_{h=1}^{H} (X_{ymdh}-\bar{X}_{ymd})^2\right]^{1/2}$$

where $\bar{X}_{ymd}$ is the mean for a given day and

$$\bar{X}_{ymd} = \frac{1}{H}\sum_{h=1}^{H} X_{ymdh} .$$

4. Computation of Frequency of Occurrence in Percent

Two different frequencies of occurrence were calculated; 3-hourly frequencies by month and monthly frequencies. The formula for 3-hourly frequencies for the occurrence of variable X in class c for a selected station is

$$fX_{cmh} = \frac{1}{YD} \sum_{y=1}^{Y} \sum_{d=1}^{D} X_{cymdh}$$

where c class of interest (e.g., west wind direction).

The variable X is either 1 or 0 depending on whether or not the value of X at the time of observation lies in class c. As an example of classes wind direction is divided into five mutually exclusive classes: north, east, south, west, and calm. Each observation must fit into one and only one of the five classes. To get frequency in percent multiply $fX_{cmh}$ by 100%.

The formula for the monthly frequency of occurrence of variable X in class c is

$$fX_{cm} = \frac{1}{YDH} \sum_{y=1}^{Y} \sum_{d=1}^{D} \sum_{h=1}^{H} X_{cymdh} .$$

## 5. Computational Notes

In the Beersheba data, especially, there were missing observations. For all data tapes the quantities YD, YDH, and H in the coefficients of the previous formulas were the actual number of observations used in a calculation. No effort was made to establish the validity of any of the data sets.

In computing the 3-hourly means, 3-hourly standard deviations, and frequencies of occurrence all available data on the magnetic tapes were used. In order to prevent bias in computing the monthly means and standard deviations the missing data for days with at least one observation were reconstructed (for each variable). That is, the data that went into these statistics were comprised of full days of data (8 values per day). The reconstruction rules for each variable were as follows:

(1) No reconstruction occurred unless there was at least one observation for the day to be reconstructed.

(2) Before any reconstruction occurred at any hour, there had to be a good observation for that hour sometime in the past.

(3) The reconstructed value is the previous available observation or previous reconstructed value at that hour.

(4) A full day of missing and/or uninterpretable values was ignored, i.e., no reconstruction was made.

In theory it would possible to have a value at, say, some hour in January, propagated for months. In practice, this didn't occur. There were 26 days at Beersheba that went unreconstructed for all variables for which monthly means were calculated, except sea-level pressure. Of the 26 days, 24 were in November and December. There were no missing days for the U.S. stations.

## V. COMPARISON OF MEANS AND FREQUENCIES OF THE PRIMARY VARIABLES

### A. Dry-bulb Temperature

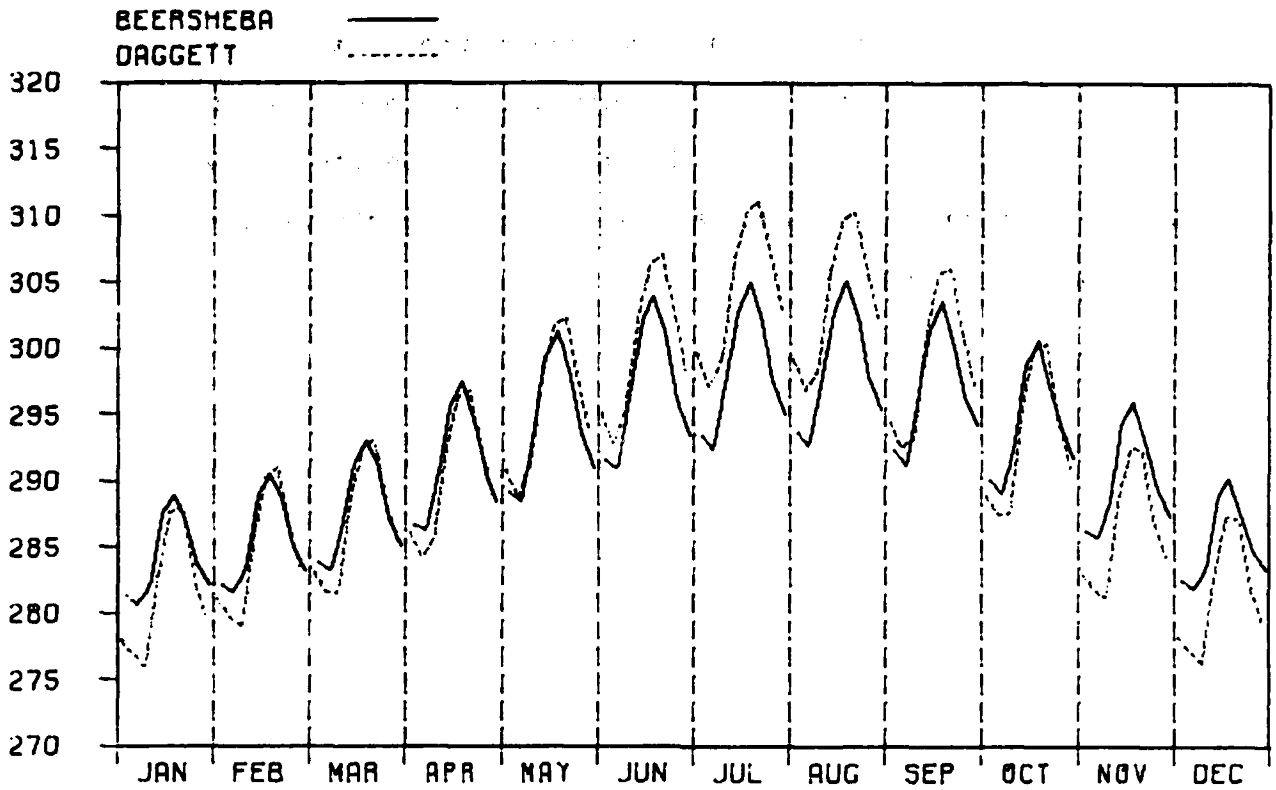
Fig. 5 shows three hourly means by month for Beersheba with Daggett, El Paso, Ft. Huachuca and Yuma. In all the figures, Beersheba data are plotted with a solid line and the data for the station that is compared with Beersheba are plotted with a dashed line. For each month the curves are comprised of straight solid or dashed lines between adjacent 3-hourly means. Solar noon is in the center of each monthly plot. Since each 3-hourly mean includes data from the first to the last of the month there is often a "jump" in values from the 2200 or 2300 observation of one month to the 0100 or 0200 observation of the next month. For this reason the monthly plots were not connected.

Fig. 5 shows that the two stations that come closest to matching Beersheba during the warm months (May-October) are El Paso and Ft. Huachuca, the former being somewhat warmer and the latter somewhat cooler than Beersheba. During the cool months (November-April) no one station provides a good model but Daggett and Yuma are better for selected months.

Fig. 6 shows the monthly means and the mean daily maximum and minimum temperatures by month. The curves are comprised of straight solid or dashed lines between adjacent monthly means. The upper curves are for maxima, the lower curves for minima and the middle curves for the means.

Again El Paso and Ft. Huachuca are better than Daggett and Yuma during the warm months, with Ft. Huachuca appearing to have the edge. *During the first half of the cool season* (November-January) Yuma matches best, with Daggett best during the second half (February-April).

Fig. 5. DRY BULB TEMP - DEG K
3-HOURLY MEANS, BY MONTH



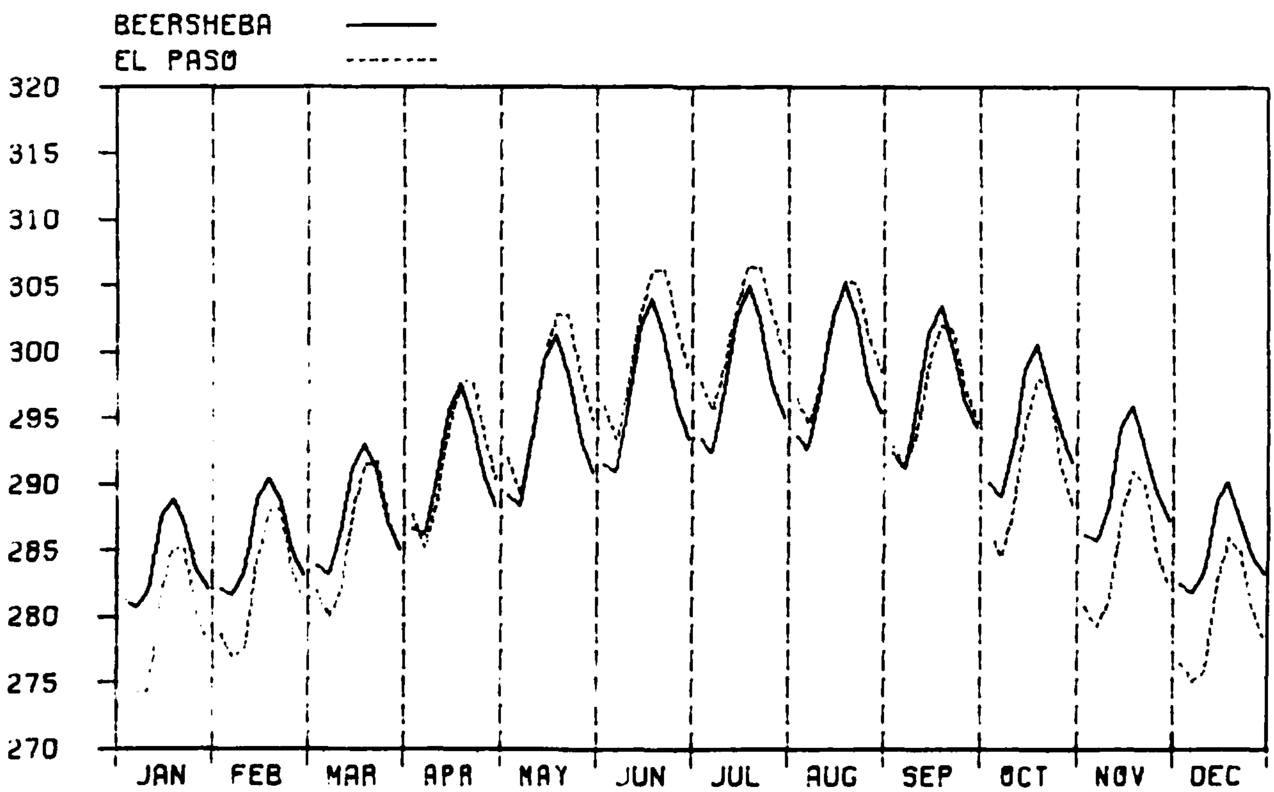
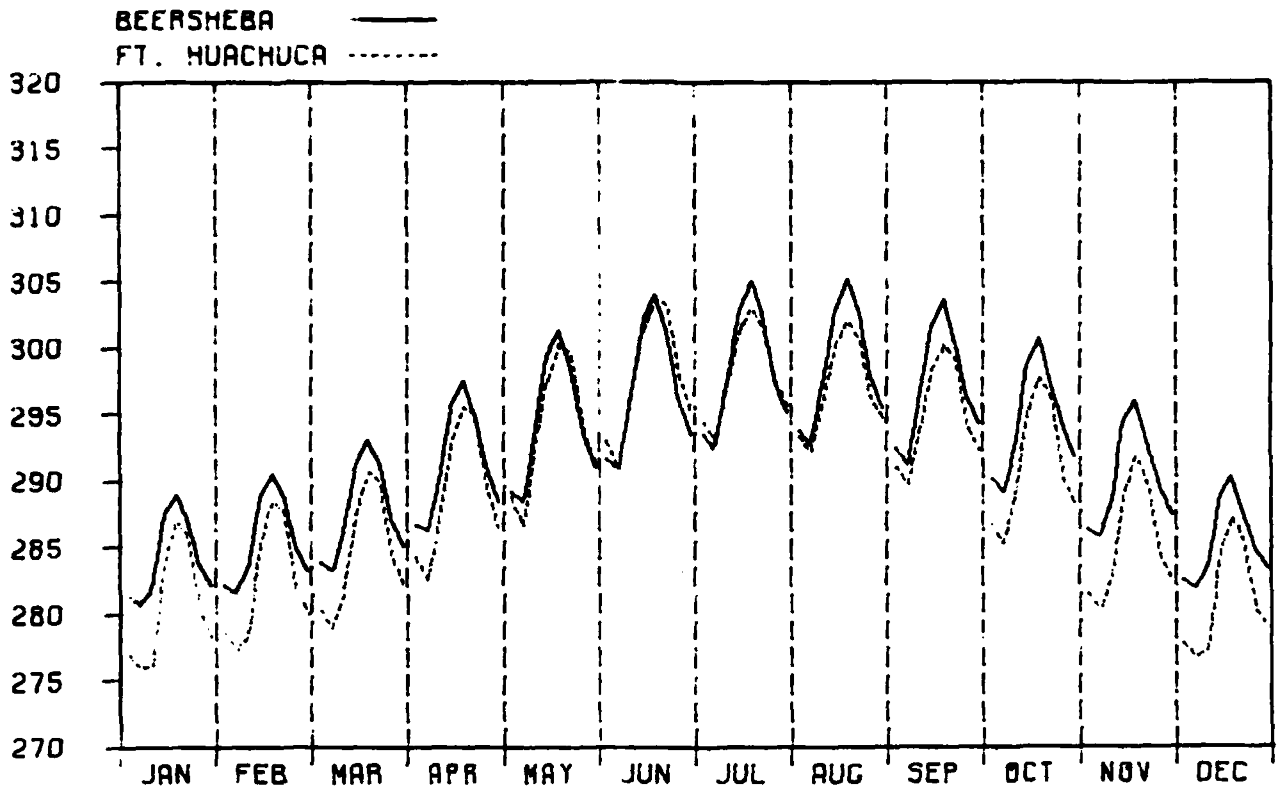



Fig. 5. (Cont'd) DRY BULB TEMP - DEG K
3-HOURLY MEANS, BY MONTH



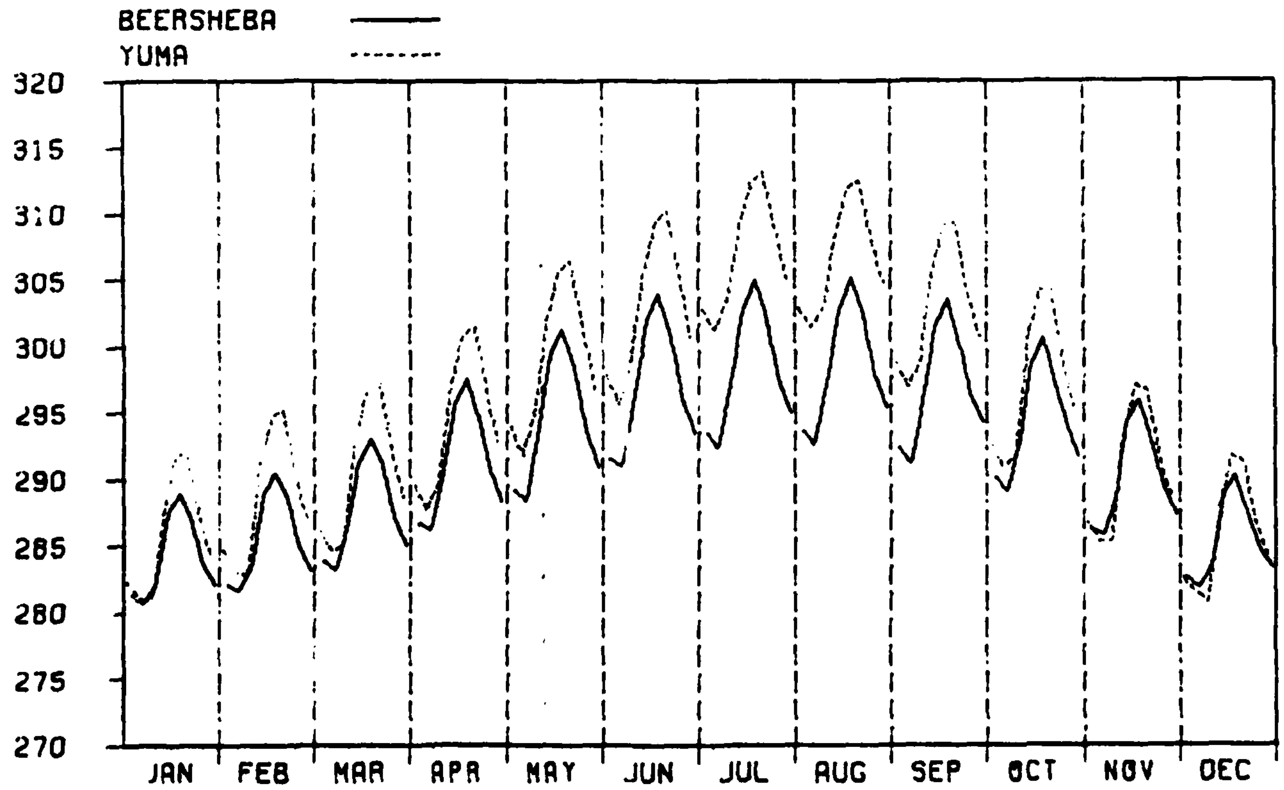
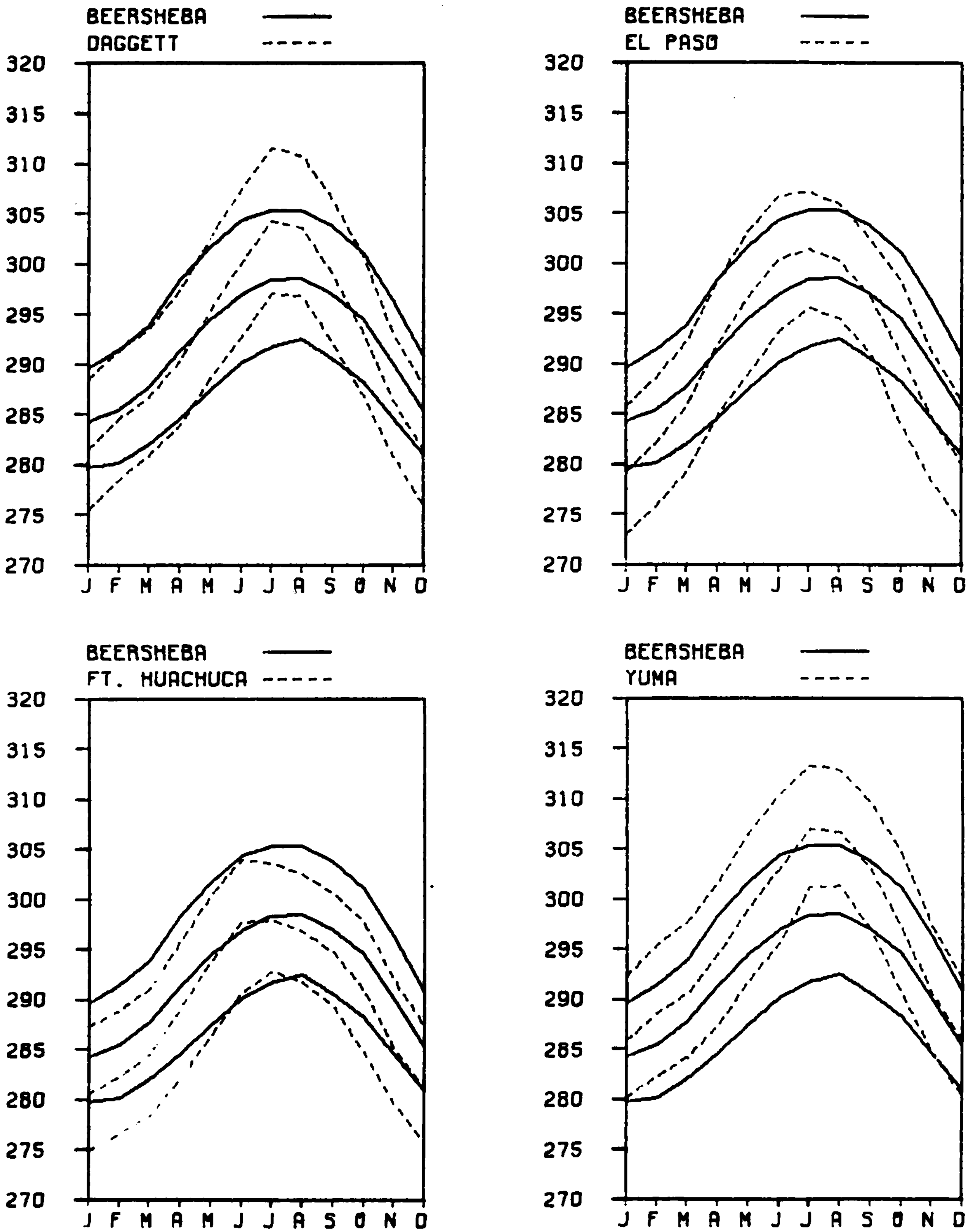



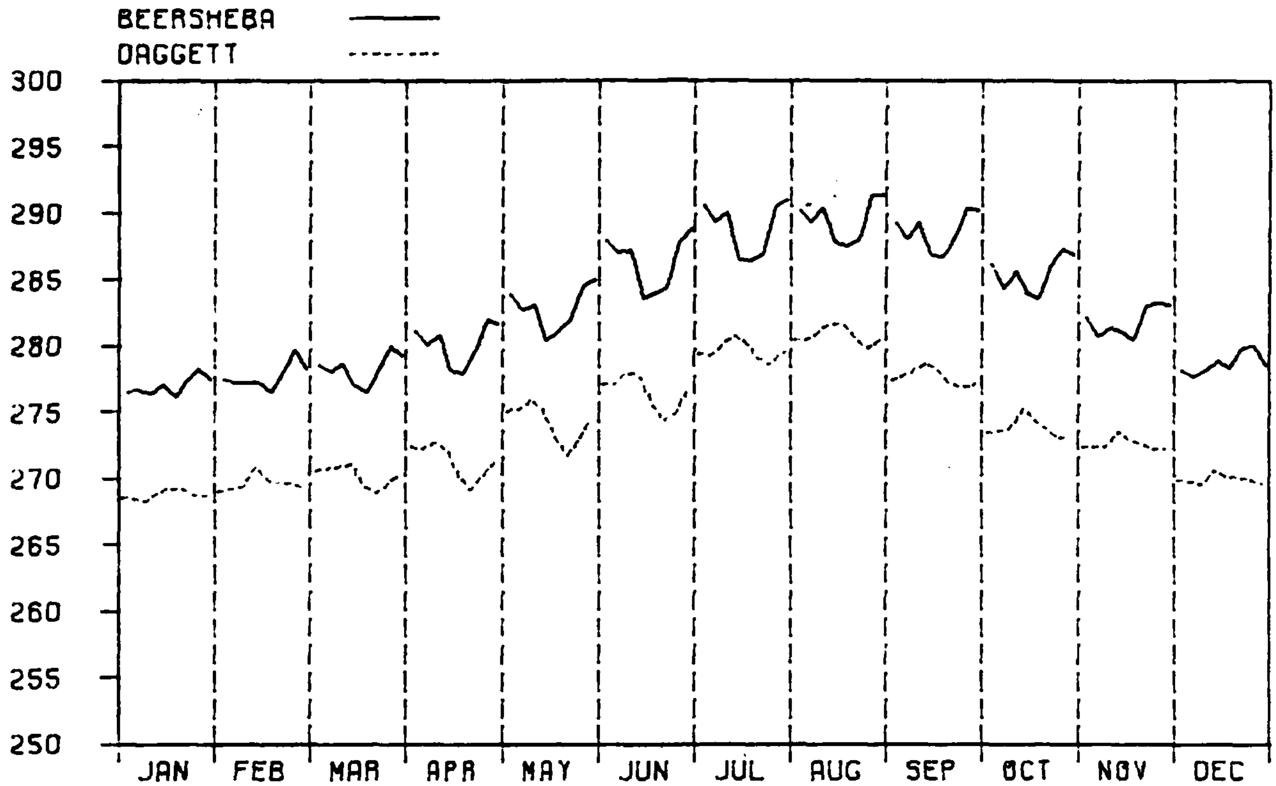
Fig. 6. DRY BULB TEMP - DEG K
MONTHLY MEANS: MEAN DAILY MAXIMA AND MINIMA, BY MONTH



## B. Dew Point

Fig. 7 shows the diurnal variation in dew point by month. El Paso, Ft. Huachuca, and Yuma show abrupt increases in moisture during the summer months as water vapor is brought in from the Gulf of Mexico to Texas and eastern Arizona and from the Gulf of California to Yuma. All U.S. stations are drier than Beersheba except for Yuma during July and August. Fig. 8 also emphasizes the sudden increase in moisture at El Paso, Ft. Huachuca and Yuma in July.

Fig. 7. DEW POINT TEMP - DEG K
3-HOURLY MEANS. BY MONTH



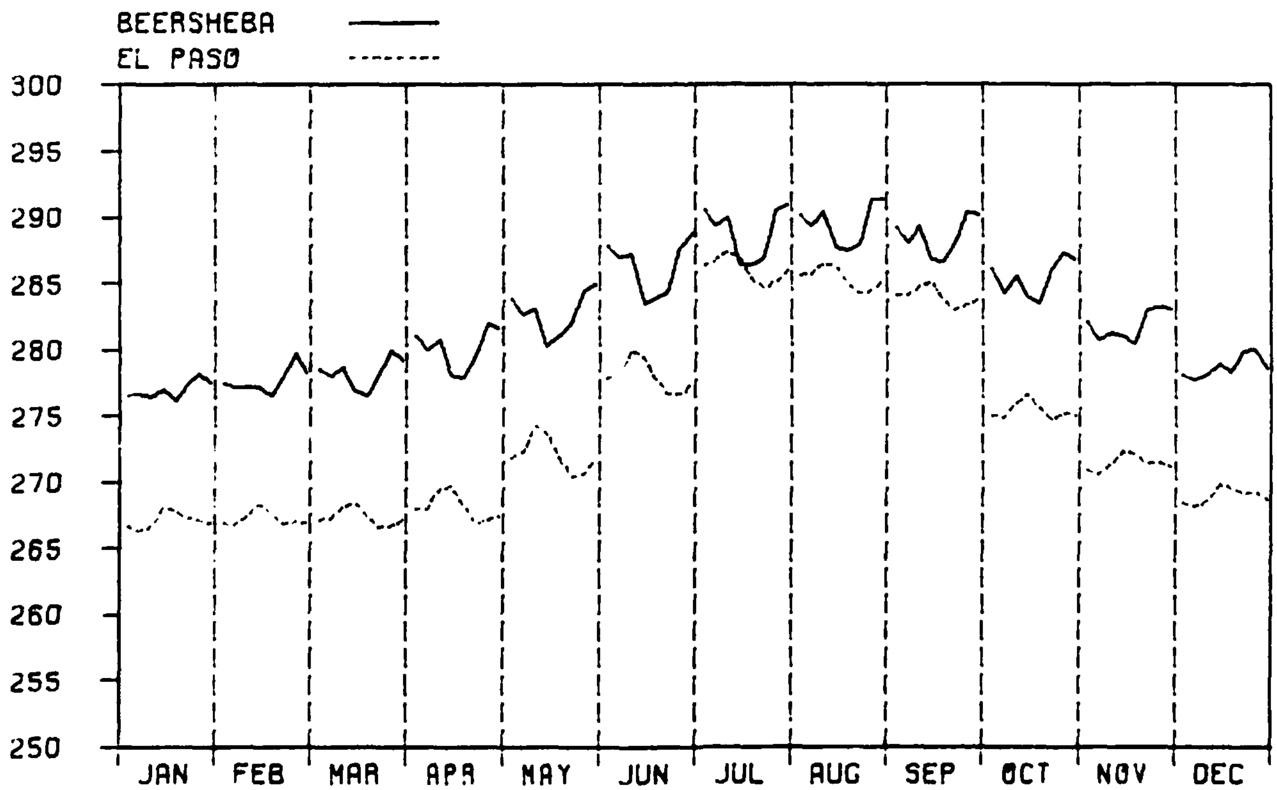
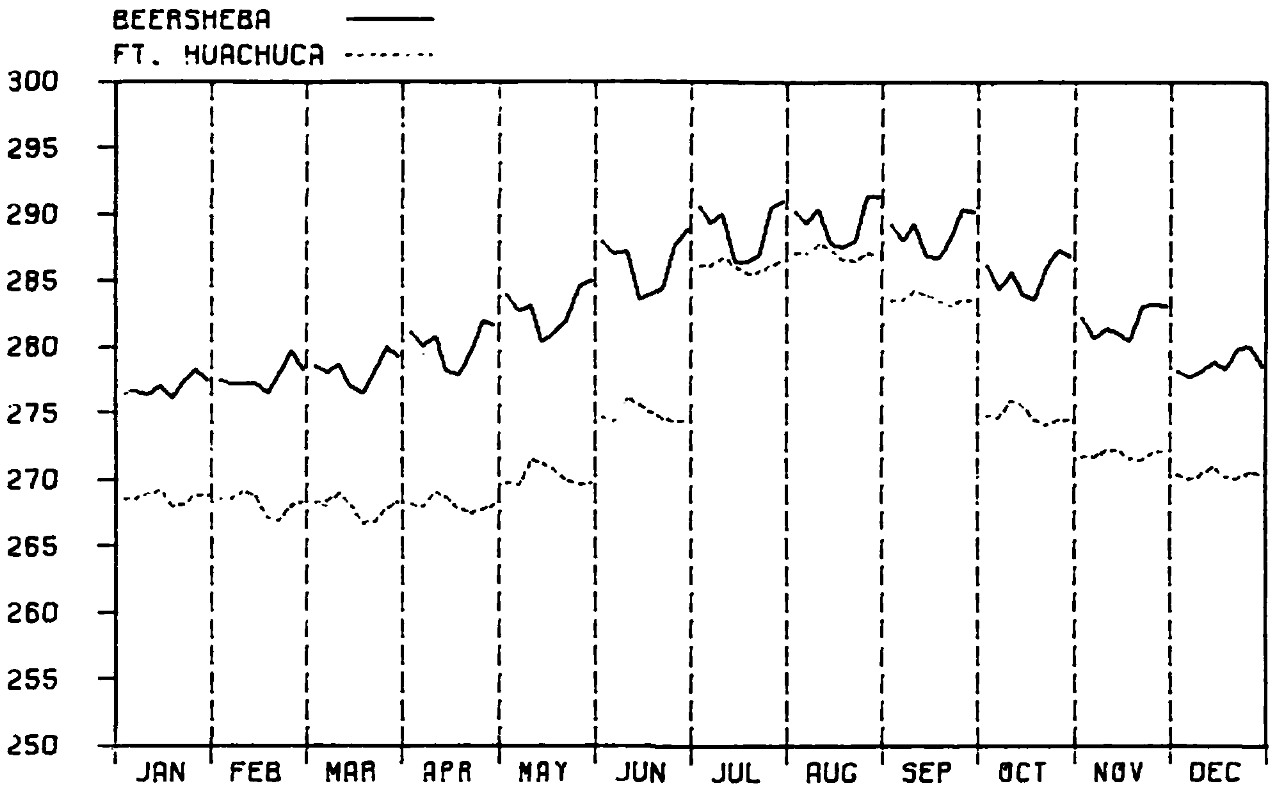



Fig. 7. (Cont'd) DEW POINT TEMP - DEG K
3-HOURLY MEANS. BY MONTH



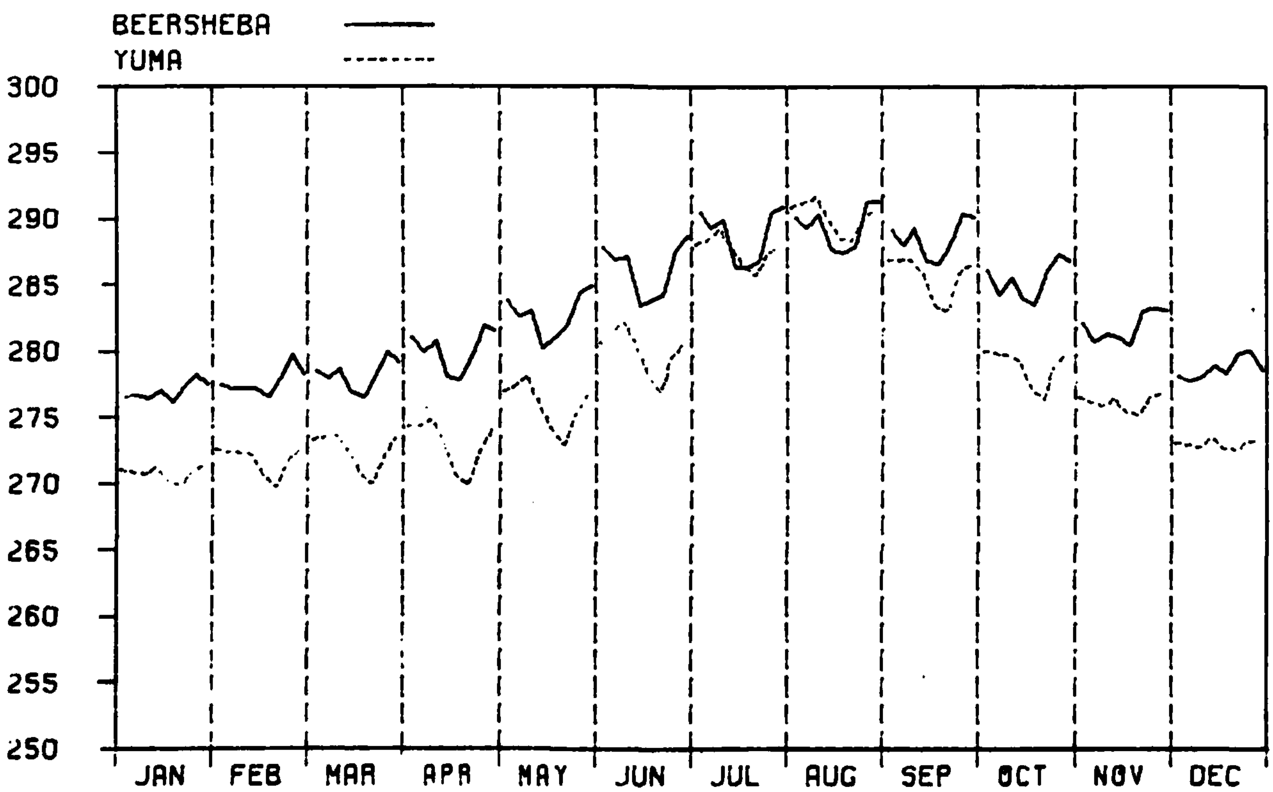
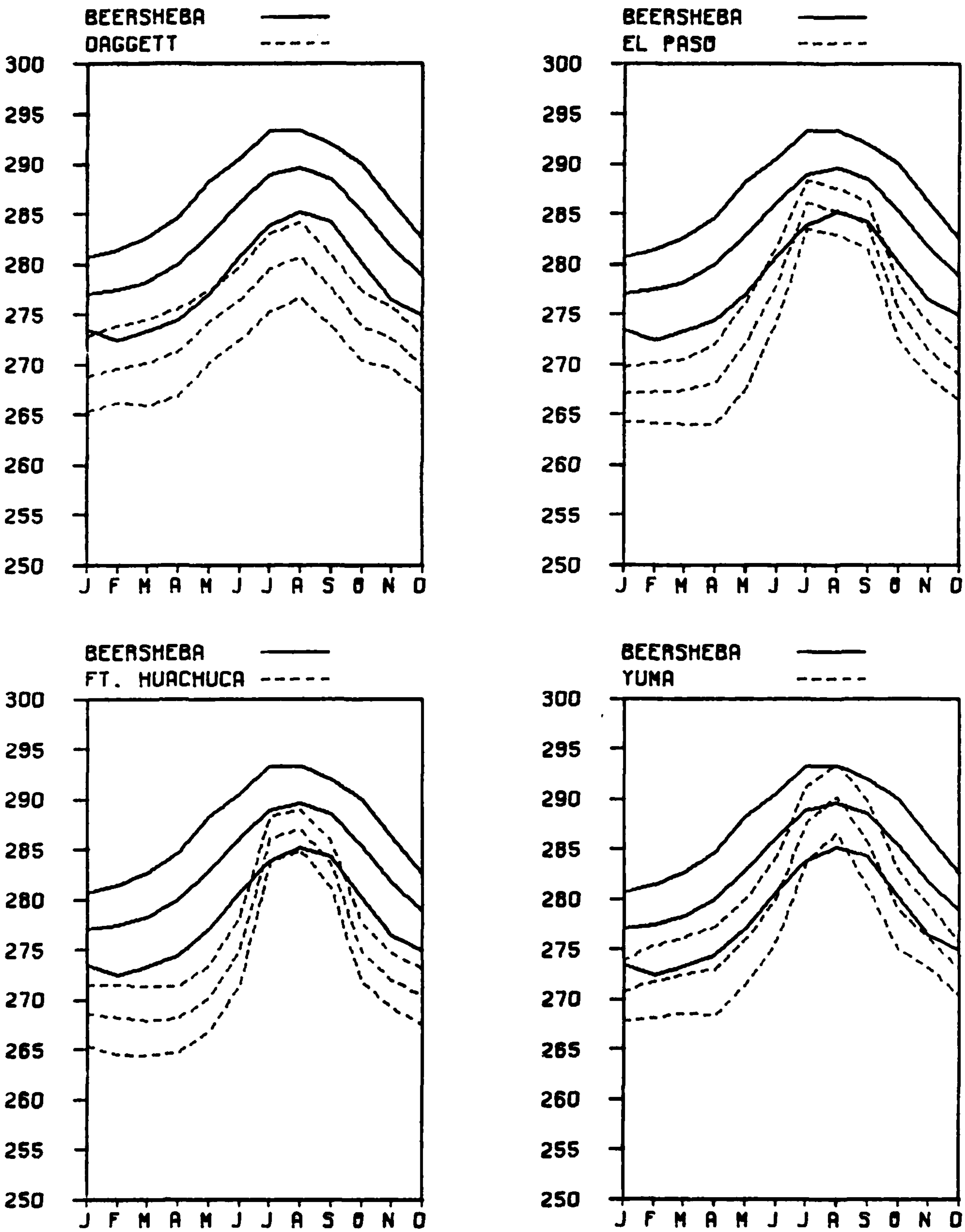



Fig. 8. DEW POINT TEMP - DEG K
MONTHLY MEANS: MEAN DAILY MAXIMA AND MINIMA, BY MONTH

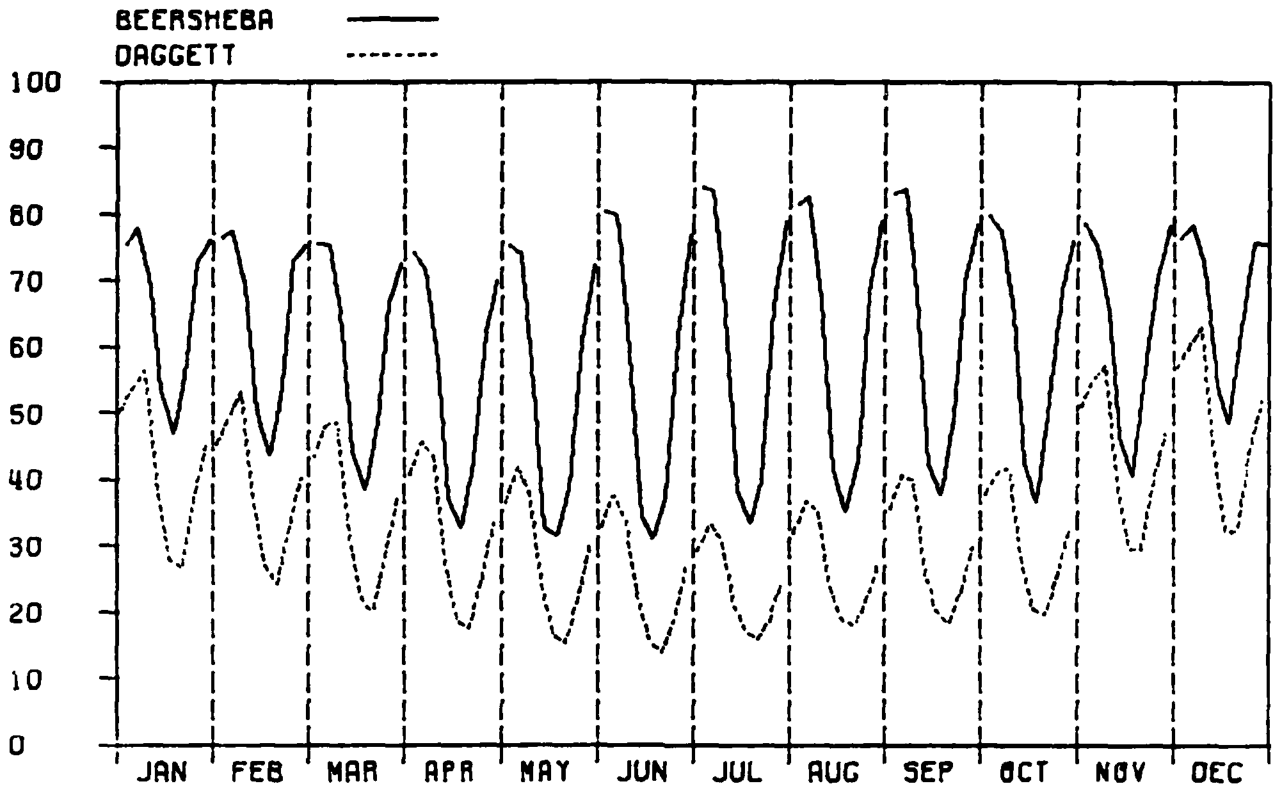


C. Relative Humidity

Fig. 9 shows the diurnal variation of relative humidity by month. Beersheba shows a steady increase in diurnal range from winter to summer, a feature not seen at the other stations. Except for the three winter months, no U.S. station exhibits the daily range at Beersheba.

Fig. 10 clearly shows the large spread between the mean daily minimum and maximum relative humidities at Beersheba - larger than any U.S. station. This must be due to the generally larger diurnal range in dew point at Beersheba and the phase relationship between temperature and dew point. Fig. 10 also shows that no U.S. station has the large magnitude of mean monthly relative humidity that occurs at Beersheba.

Fig. 9. REL. HUMIDITY - PER CENT
3-HOURLY MEANS. BY MONTH



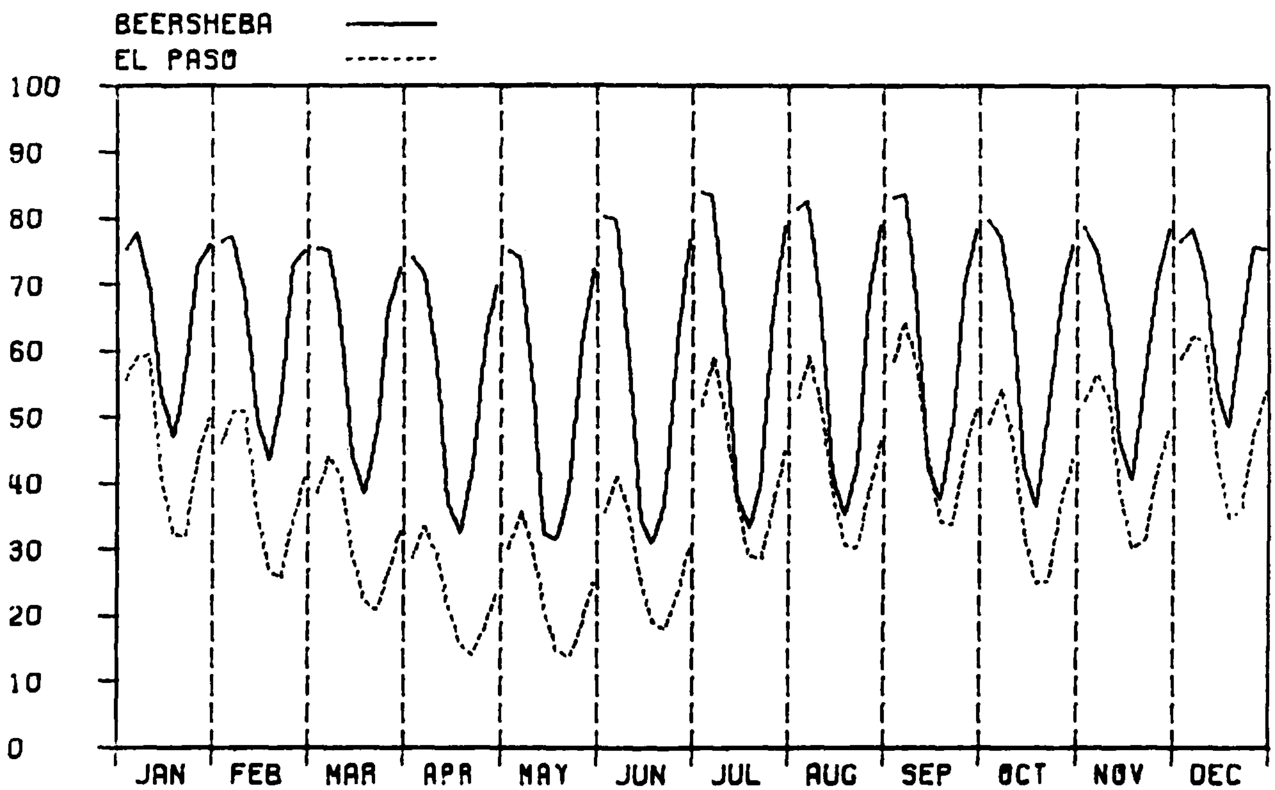
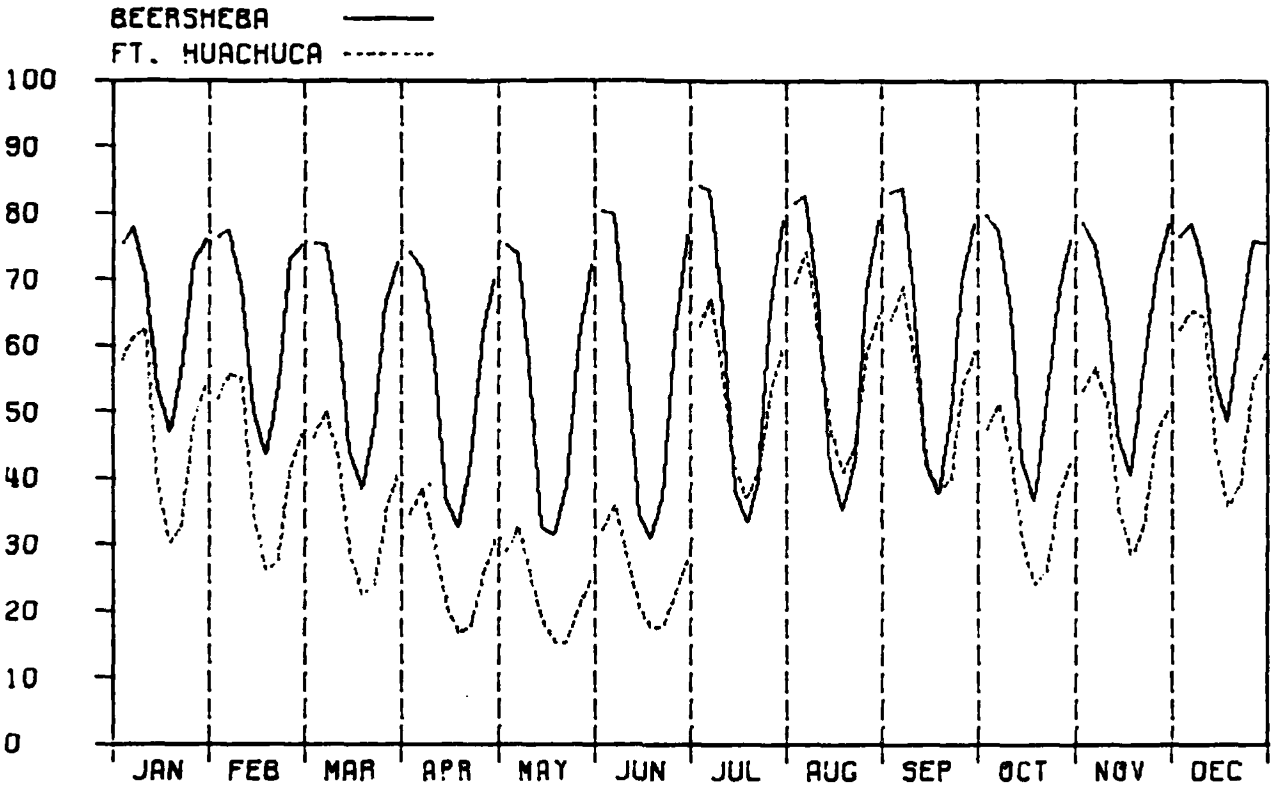



Fig. 9. (Cont'd) REL. HUMIDITY - PER CENT
3-HOURLY MEANS. BY MONTH



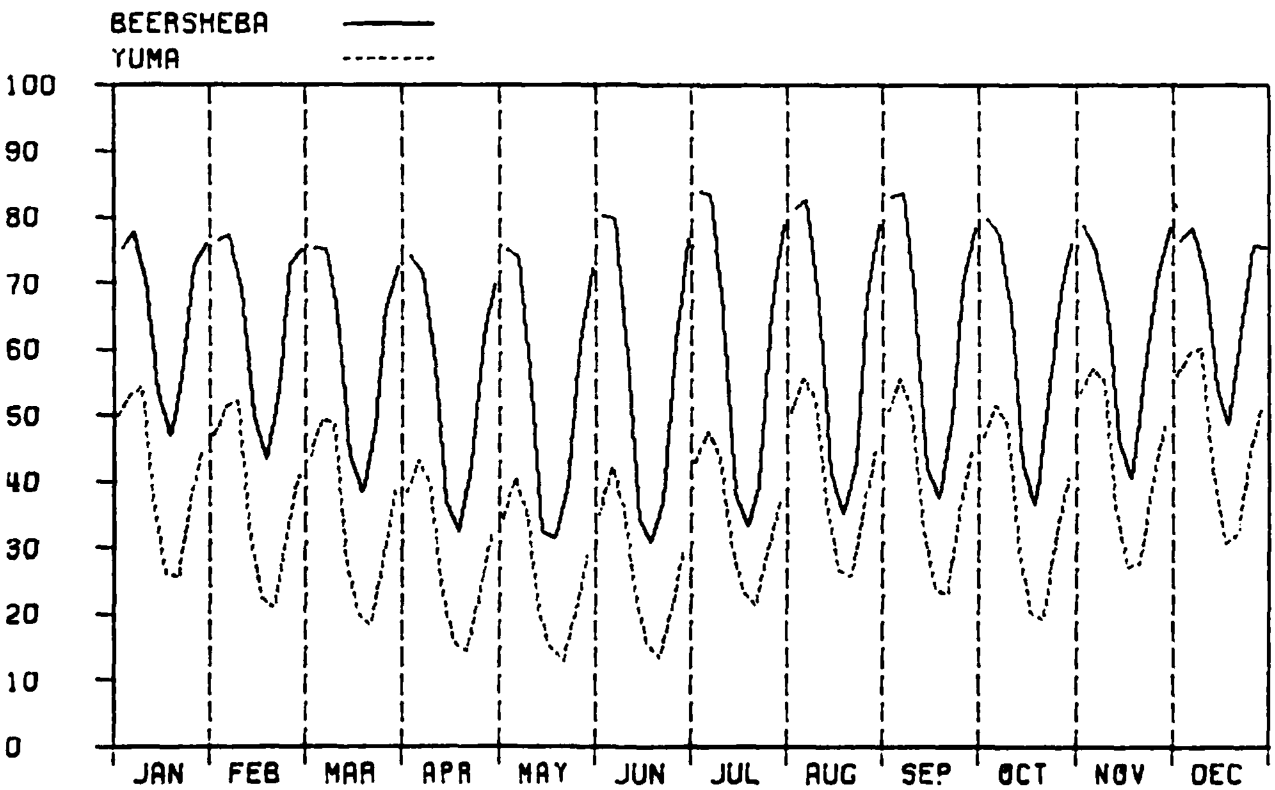
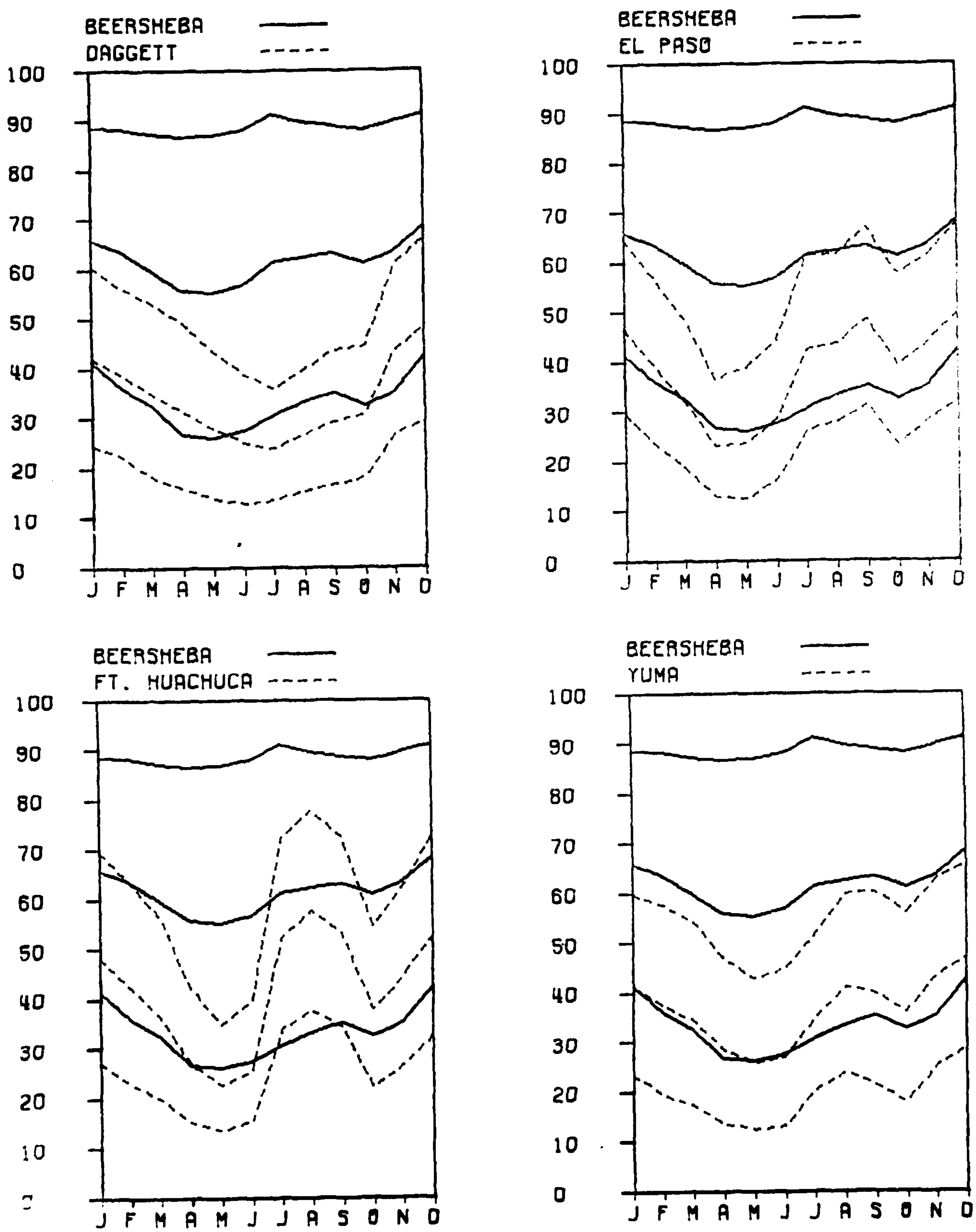



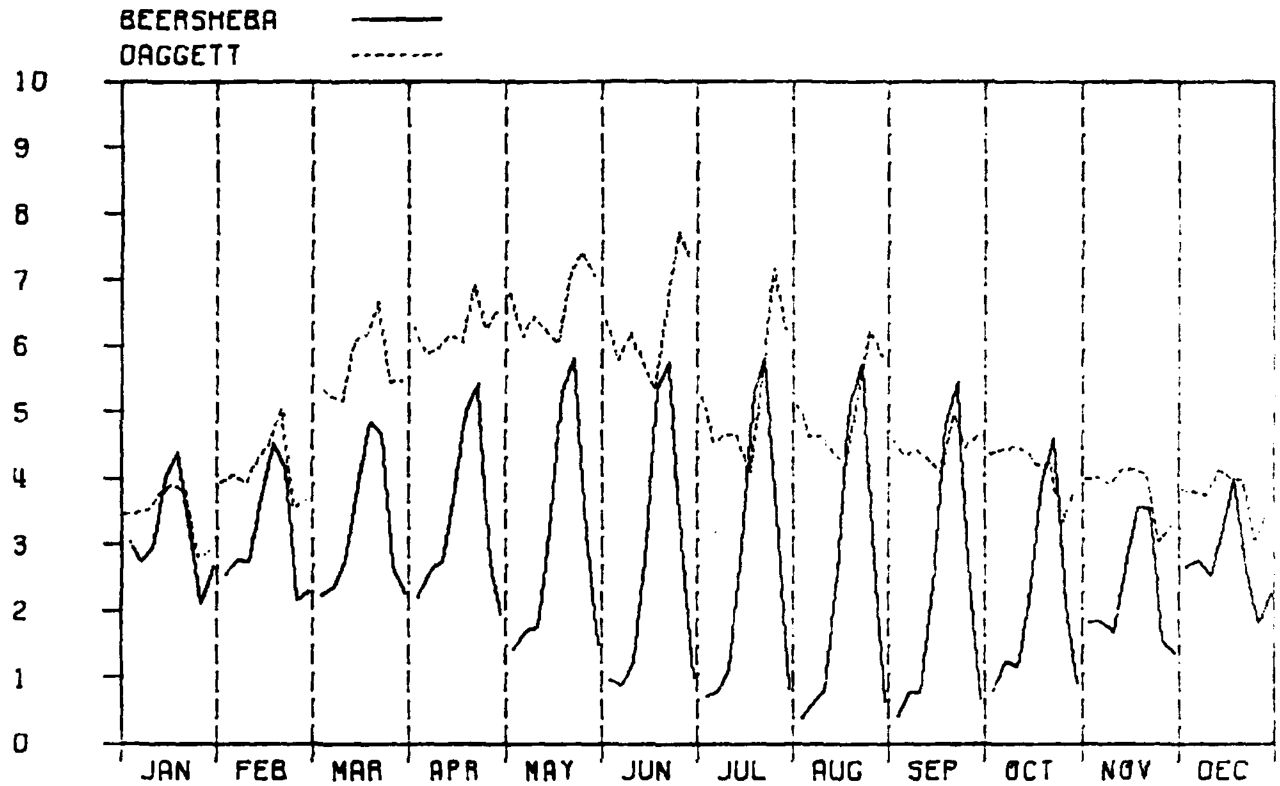
Fig. 10. REL. HUMIDITY - PER CENT
MONTHLY MEANS: MEAN DAILY MAXIMA AND MINIMA, BY MONTH



D. Wind Speed

Fig. 11 shows the diurnal variation by month of wind speed. As with relative humidity, Beersheba shows a strong annual cycle in daily wind speed range. The only station that begins to approach the range is Ft. Huachuca. In order for Beersheba to have 3-hourly average wind speeds less than 0.5 $ms^{-1}$ there must be many occurrences of calm wind. Indeed, as Fig. 12 shows, the mean daily minimum at Beersheba is very close to zero during the summer months. In contrast to the strong annual cycle in daily range at Beersheba compared to the U.S. stations Fig. 12 indicates the opposite is true of the annual cycle in monthly means. Fig. 12 shows that Ft. Huachuca, again, would yield the best model of Beersheba wind speed.

Fig. 11. WIND SPEED - METERS/SEC
3-HOURLY MEANS. BY MONTH



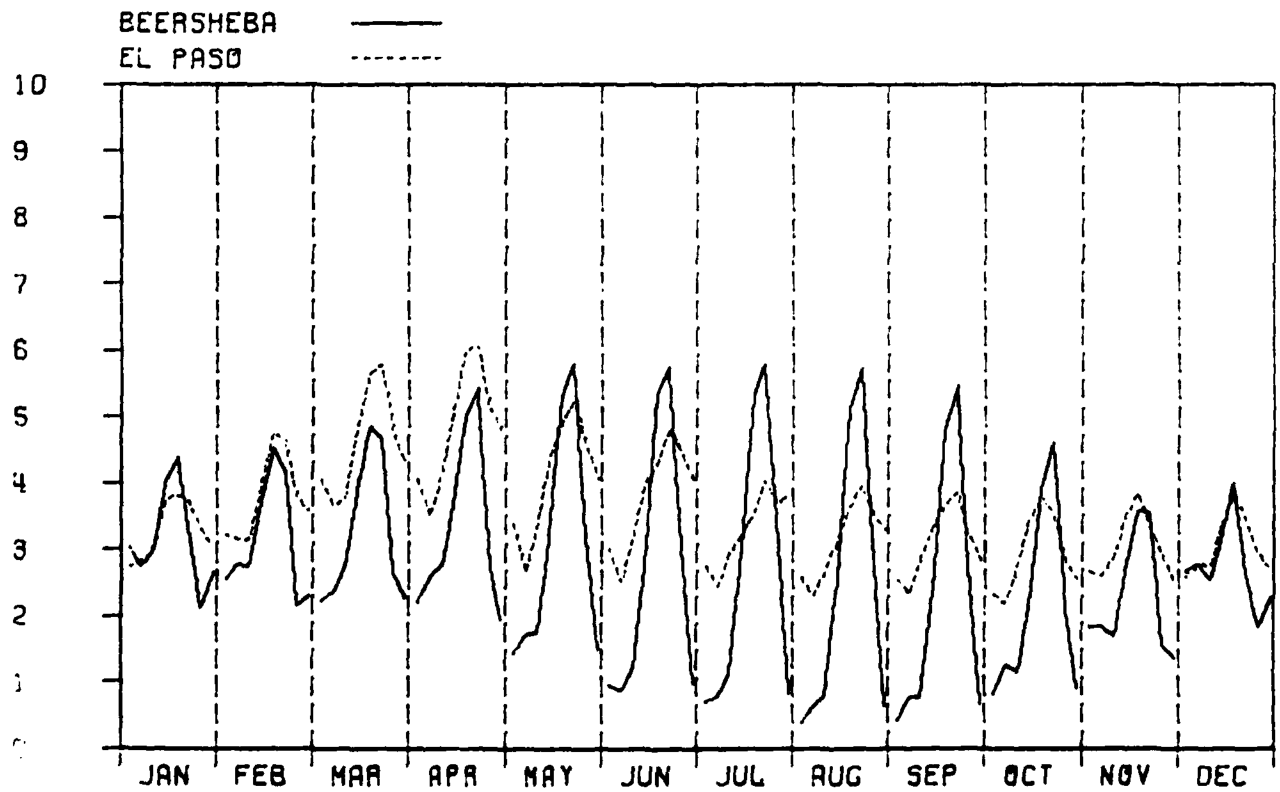
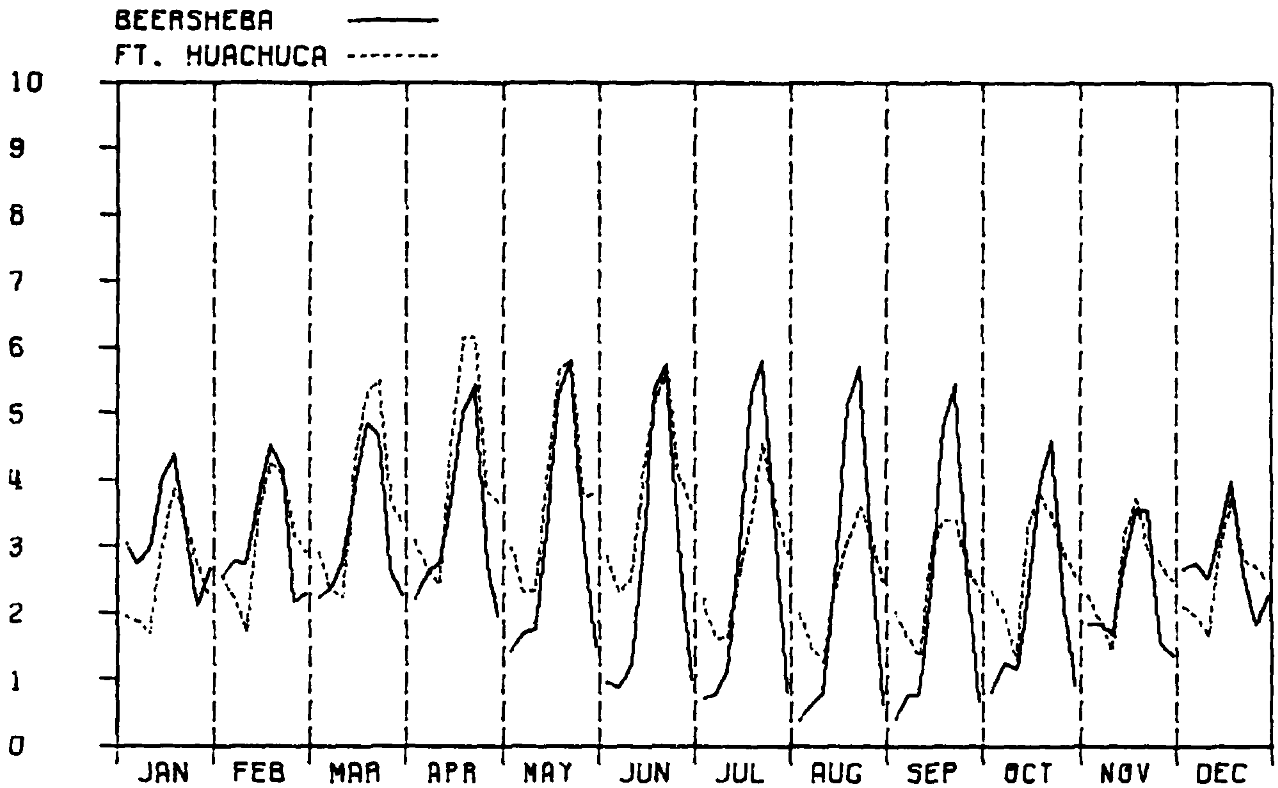



Fig. 11. (Cont'd) WIND SPEED - METERS/SEC
3-HOURLY MEANS, BY MONTH



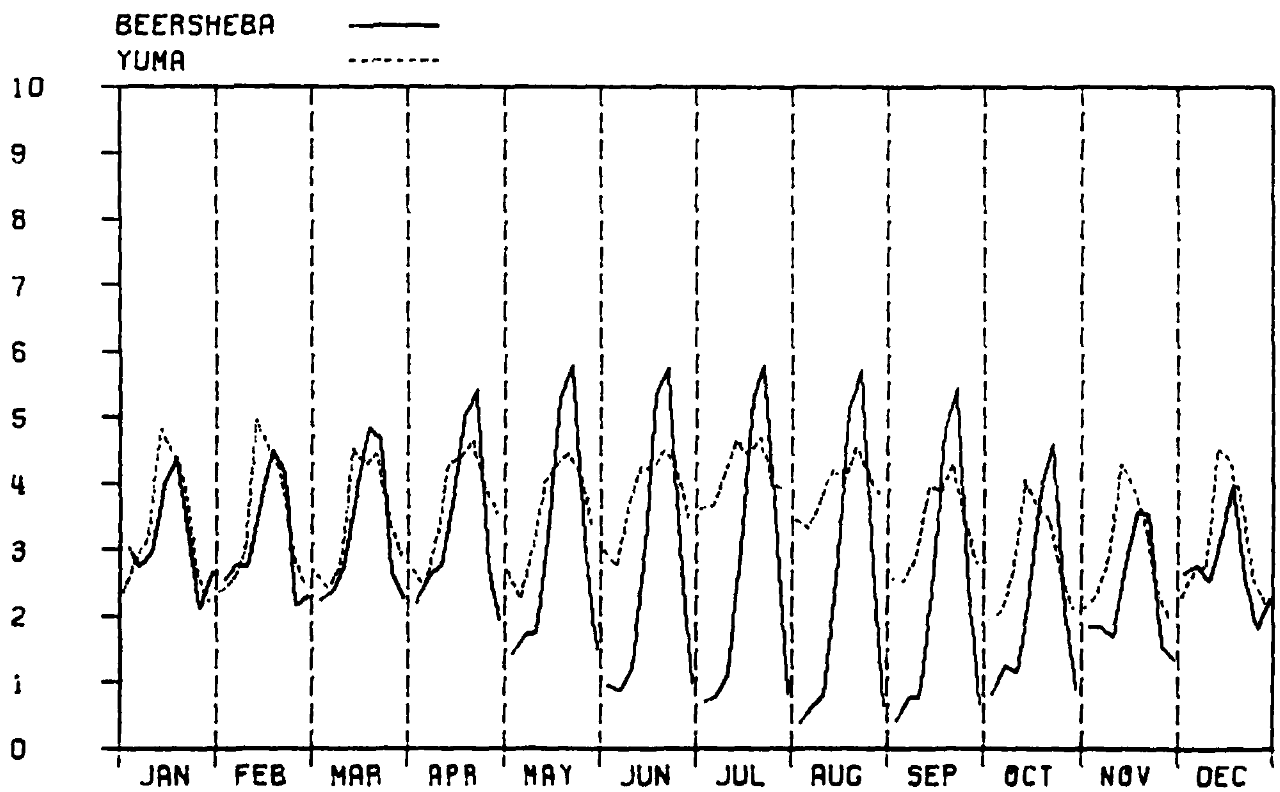
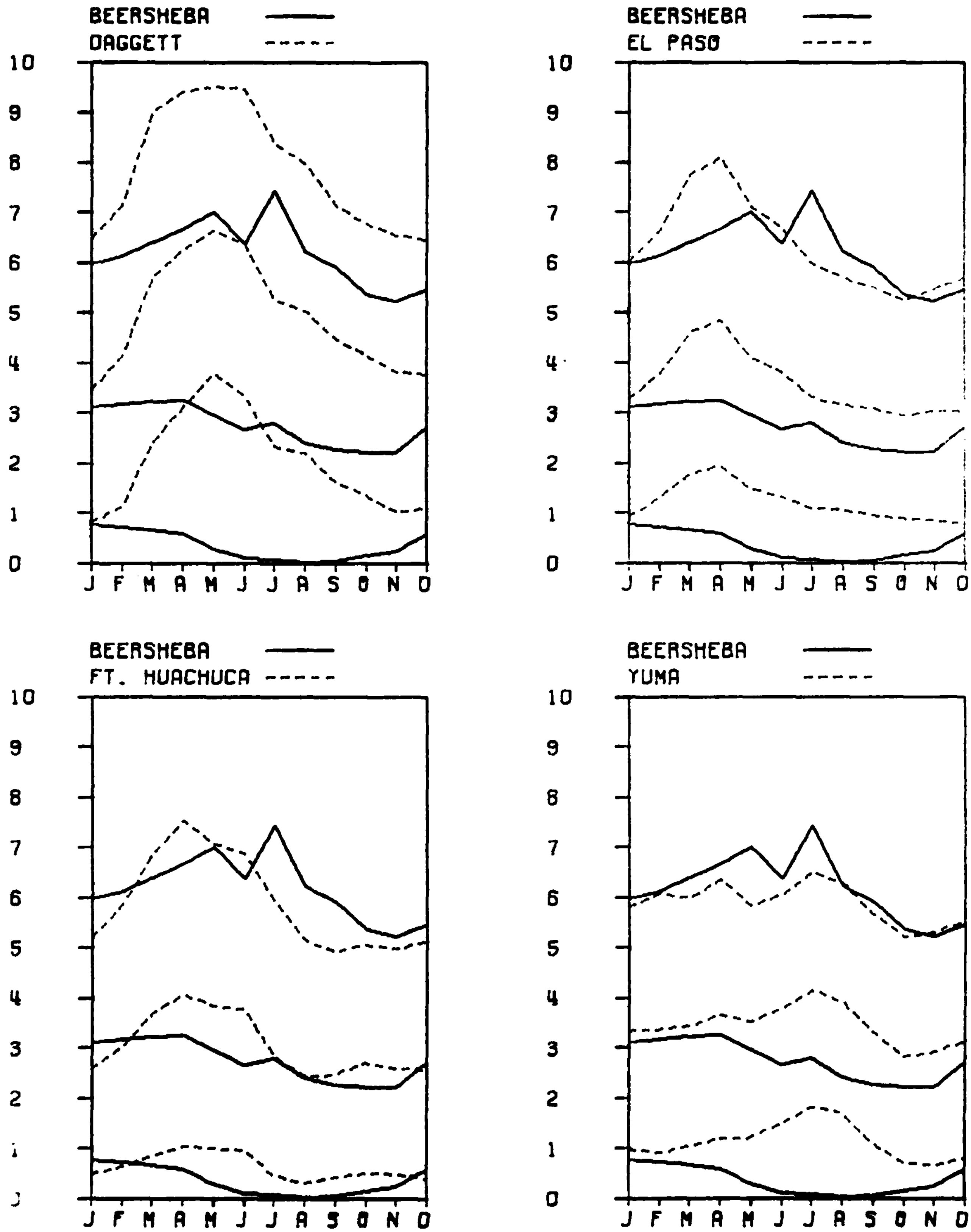



Fig. 12. WIND SPEED - METERS/SEC
MONTHLY MEANS: MEAN DAILY MAXIMA AND MINIMA, BY MONTH



## E. Atmospheric Stability Index

### 1. Method of Computation

Before examining the comparative results for atmospheric stability the method of computation will be discussed. Atmospheric stability is a measure of the vertical mixing of air. Pasquill [8, 9] developed a scheme for categorizing stability in the surface layer (surface to 300 m) using as inputs total sky cover (TSC), solar altitude and surface wind speed. The categories are numbered 1 through 7 (hereafter referred to as stability index) from unstable to stable conditions.

Table 4 shows the seven categories as a function of wind speed, insolation and TSC. The insolation is determined from the solar altitude at the time of observation according to Table 5, in which Cr corresponds to the solar altitude one hour after sunrise. Depending on the amount of clouds present, the strength of the insolation can be reduced from the clear sky value, as shown in Table 6. As an example, if the solar altitude were 42° with 5/8 total sky cover and a wind speed of 2.7 $ms^{-1}$ the insolation from Table 6 would be "weak" and the stability index from Table 4 would be 3. Other conditions being the same, if it were nighttime the stability index would be 5.

Table 4. Stability index for differing amounts of wind speed, insolation and TSC (total sky cover).

| Wind Speed ($ms^{-1}$) | Daytime* Insolation Strong | Moderate | Weak | Nighttime* TSC≥0.5 | TSC≤0.4 |
|---|---|---|---|---|---|
| 0.0 to < 1.0 | 1 | 1 | 2 | 6 | 7 |
| 1.0 to < 2.0 | 1 | 2 | 2 | 6 | 7 |
| 2.0 to < 2.5 | 1 | 2 | 3 | 5 | 6 |
| 2.5 to < 3.0 | 2 | 2 | 3 | 5 | 6 |
| 3.0 to < 4.0 | 2 | 2 | 3 | 4 | 5 |
| 4.0 to < 5.0 | 2 | 3 | 3 | 4 | 5 |
| 5.0 to < 5.5 | 3 | 3 | 4 | 4 | 4 |
| ≥ 5.5 | 3 | 4 | 4 | 4 | 4 |

*If TSC = 1.0 the stability index is 4.

Table 5. The strength of clear sky insolation as a function of solar altitude.

| Solar Altitude (deg) | Clear Sky Insolation |
|---|---|
| <Cr | Nighttime |
| ≥Cr to 35 | Weak |
| >35 to 60 | Moderate |
| >60 | Strong |

Table 6. The strength of cloudy sky insolation as a function of total sky cover (TSC).

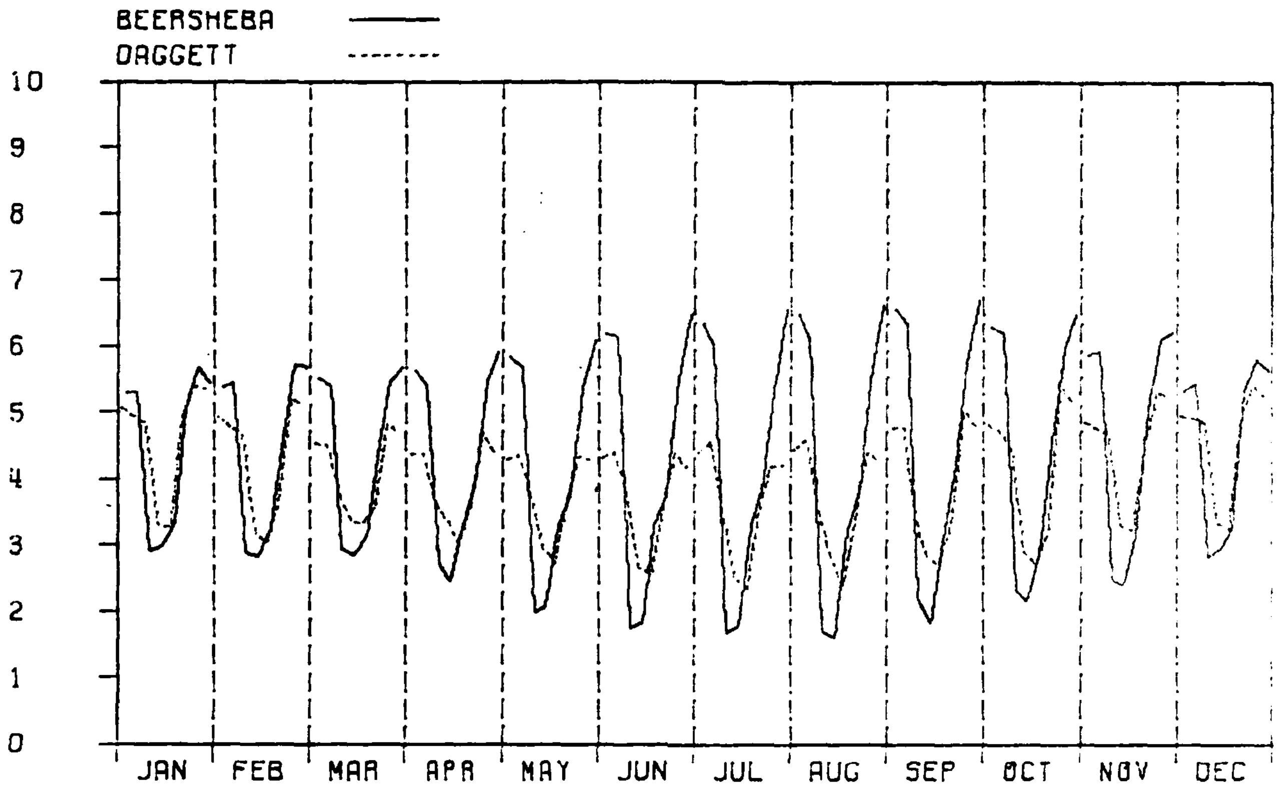
| TSC | Clear Sky Insolation | Cloudy Sky Insolation |
|---|---|---|
| 0/8-4/8 or 0/10-5/10 | Strong | Strong |
| 5/8-6/8 or 6/10-8/10 | | Moderate |
| 7/8 or 9/10 | | Weak |
| 0/8-4/8 or 0/10-5/10 | Moderate | Moderate |
| 5/8-7/8 or 6/10-9/10 | | Weak |
| 0/8-7/8 or 0/10-9/10 | Weak | Weak |

## 2. Comparative Analysis

In Fig. 13 all stations show a systematic increase in the range of stability index from winter to summer. All U.S. stations except Yuma provide reasonable fits to Beersheba during the cool season, but none fit well during the warm season. According to the method of calculating stability the air reaches its maximum instability around solar noon for the U.S. stations but a couple of hours earlier at Beersheba. That it occurs before noon is a consequence of low wind speed and adequate insolation. The maximum stability typically occurs around midnight at Beersheba when the wind speed is lowest but often around 0500 at the U.S. stations when their wind speed is lowest (see Fig. 11).

As seen in Fig. 14 Beersheba has the least annual variation in monthly mean stability among the five stations. As expected from Fig. 13 Beersheba also has the smallest daily minimum and largest daily maximum. El Paso and Ft. Huachuca provide the better fits to Beersheba.

Fig. 13. STABILITY INDEX - 1 TO 7
3-HOURLY MEANS, BY MONTH



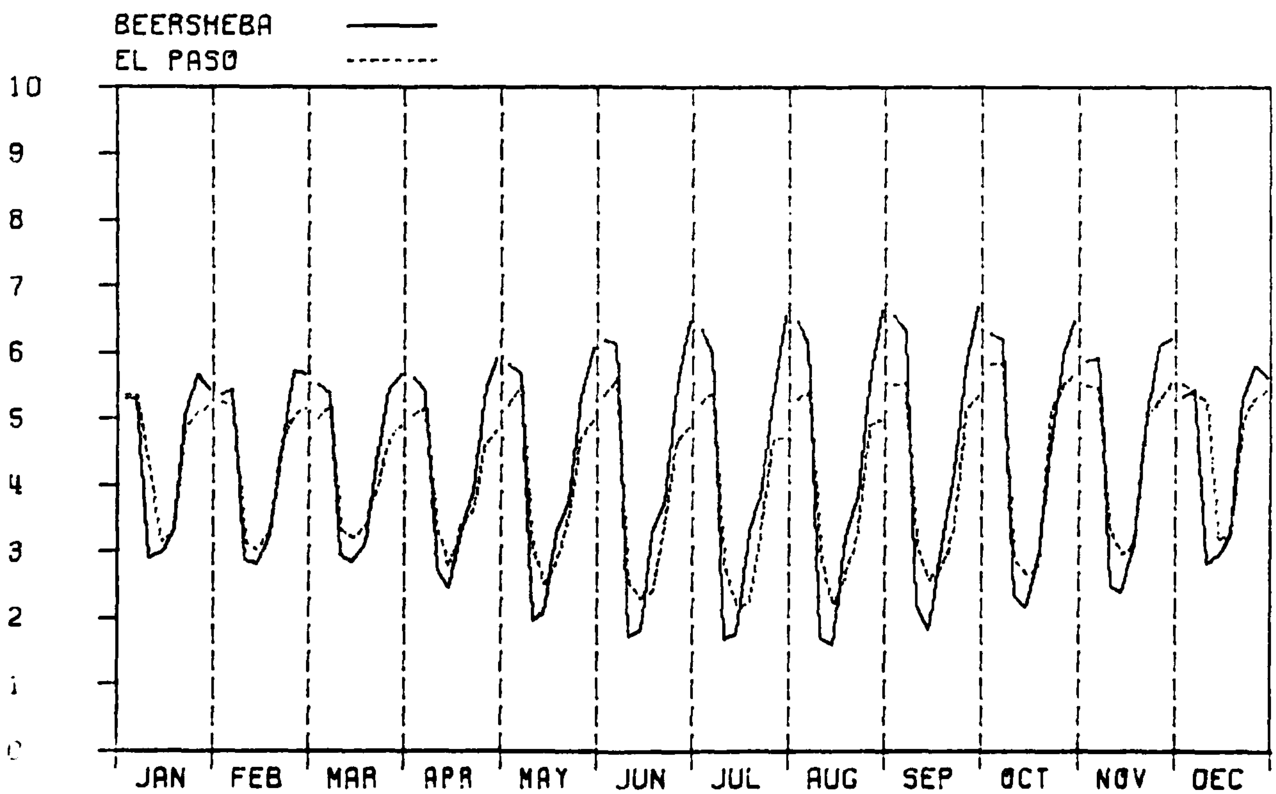
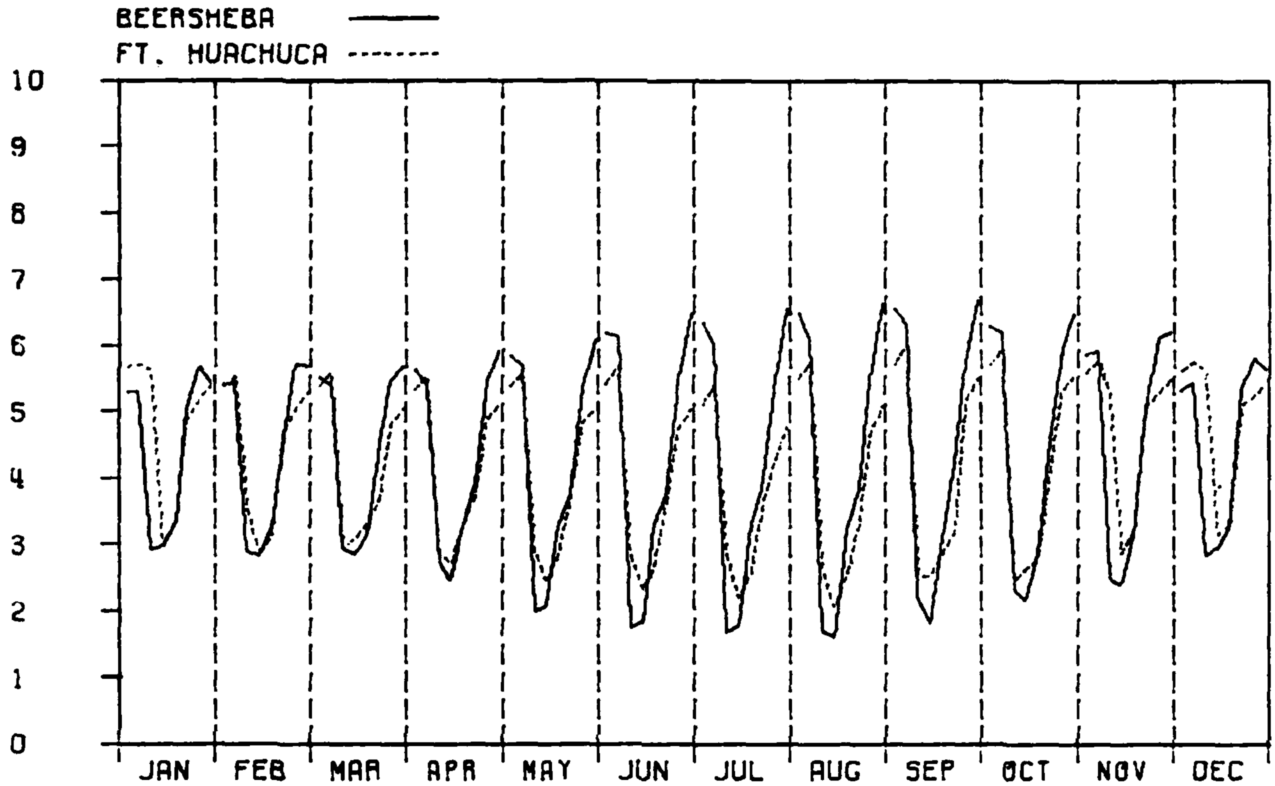



Fig. 13. (Cont'd) STABILITY INDEX - 1 TO 7
3-HOURLY MEANS. BY MONTH



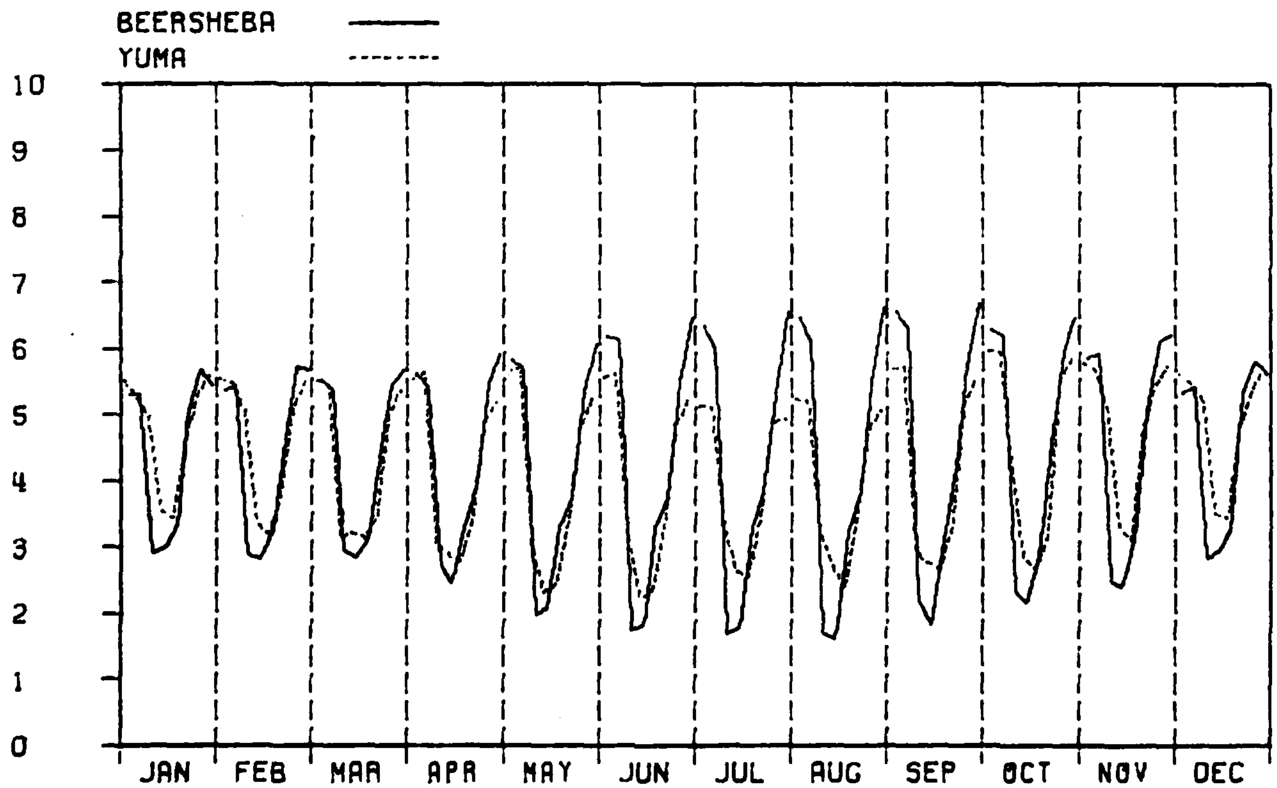
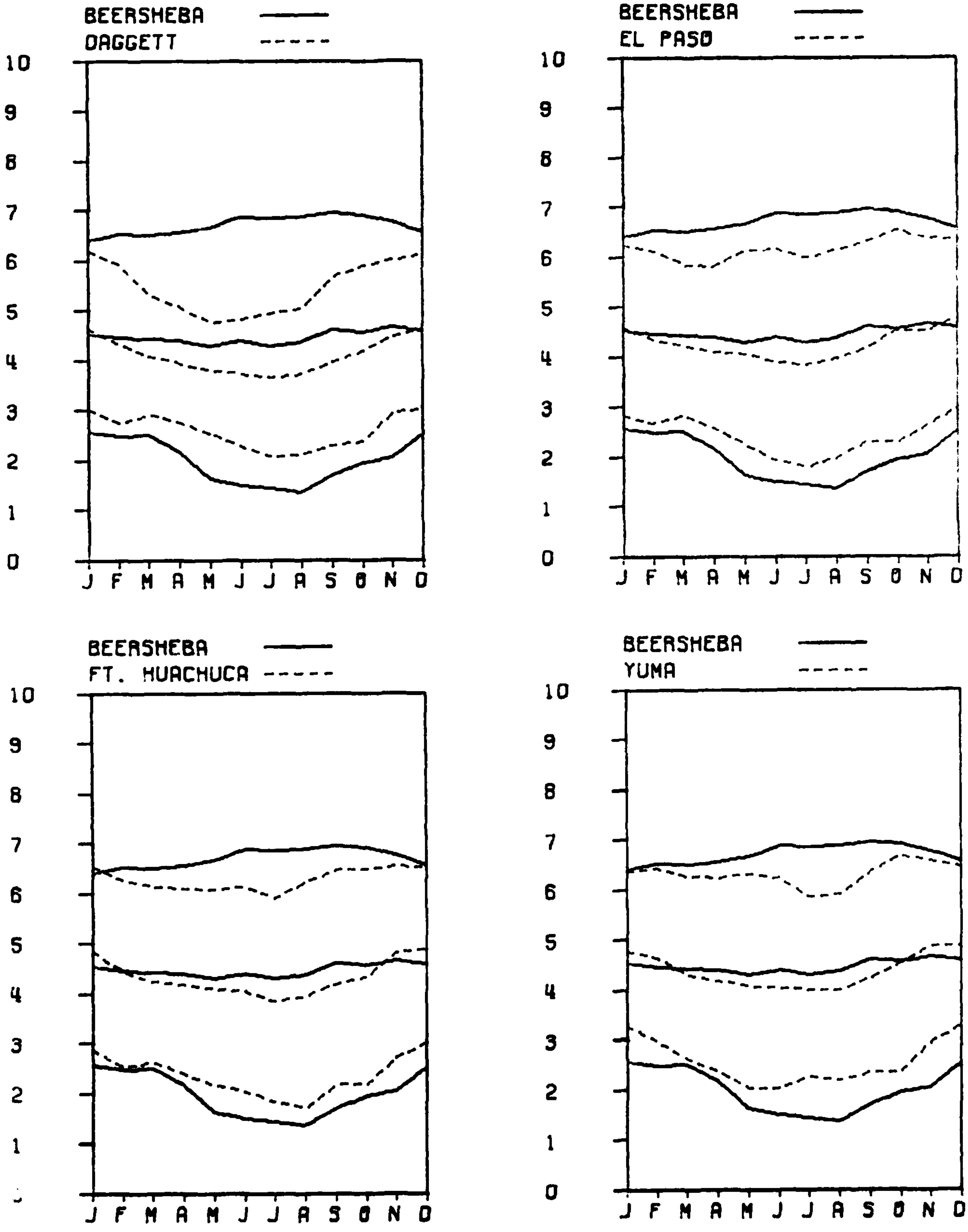



Fig. 14. STABILITY INDEX - 1 TO 7
MONTHLY MEANS: MEAN DAILY MAXIMA AND MINIMA, BY MONTH



## F. Visibility

Fig. 15 includes the four classes of visibility: less than or equal to 1 km, greater than 1 km to 5 km, greater than 5 km to 10 km, and greater than 10 km. The ordinate in each case is frequency of occurrence in percent. If the value for one of the visibility classes at a given 3-hourly observation were 10% this means that the visibility would fall into that class at that hour on the average of 3 days in a 30 day month (0.10 x 30 days). Another interpretation would be that there is a 10% chance of the visibility being in that class at that hour on any selected day of the month. This assumes no preferred period of occurrence during the month or from year to year.

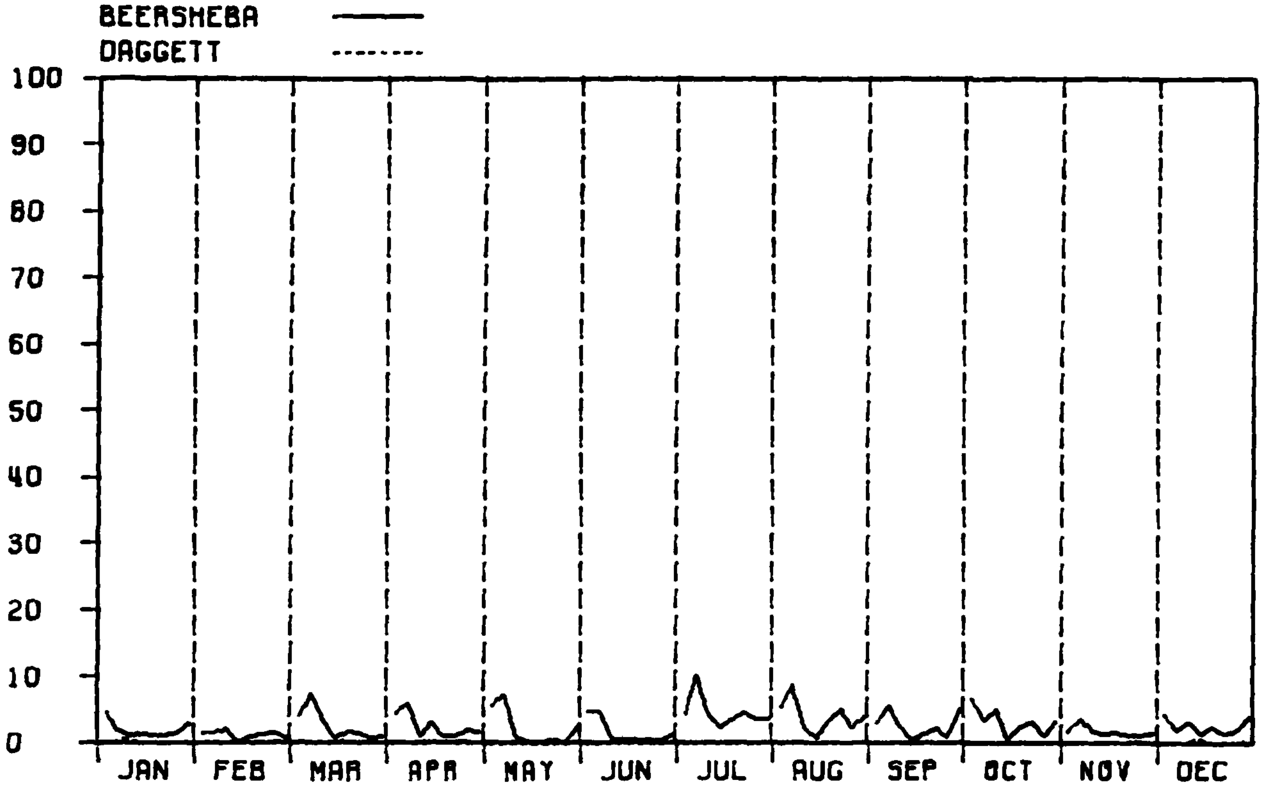
A scan of the four classes quickly reveals that the occurrence of some type of obscuration is far more prevalent at Beersheba than at any of the U.S. stations. At Beersheba the visibility is less than or equal to 1 km about 3 times each July at 0500 IST. The visibility is between 1 and 5 km about 6 times at 0500 IST during each of the summer months (June-August). The only U.S. station that shows any significant obscuration is El Paso during the cool season (November-April) in the 1 to 5 km class. The >10 km class portrays the common occurrence of "poor" visibility ($\leq$10 km) in the night-time hours and "good" visibility (>10 km) in the daylight hours at Beersheba. This daily pattern is generally not found at the U.S. stations (but see Daggett). It should be pointed

out that all Beersheba observations are reported to be taken according to WMO (World Meteorological Organization) standards [10].

The meaning of the frequency in percent in Fig. 16 can be understood by example. If the value for a given month were 10% then in a 30 day month there would be on the average 24 observations in that class (0.10 x 8 obs per day x 30 days). The interpretation in terms of percent chance of occurrence is the same as that for Fig. 15 except that it applies to any 3-hourly observation throughout the month.

Fig. 16 shows that over the course of a year the monthly frequencies for any of the classes for any station change by less than 10%. With reference to Beersheba the visibility at Ft. Huachuca and Yuma is almost always very good. At Daggett and El Paso, the percentage of time the visibility is "poor" ($\leq$10 km) varies from about 1 to 3%, and in most of these occurrences the visibility is better than 1 km.

Fig. 15. VISIBILITY - KM
CLASS (MAX) = 1
FREQUENCY (IN PER CENT), BY 3-HOURLY PERIOD AND BY MONTH



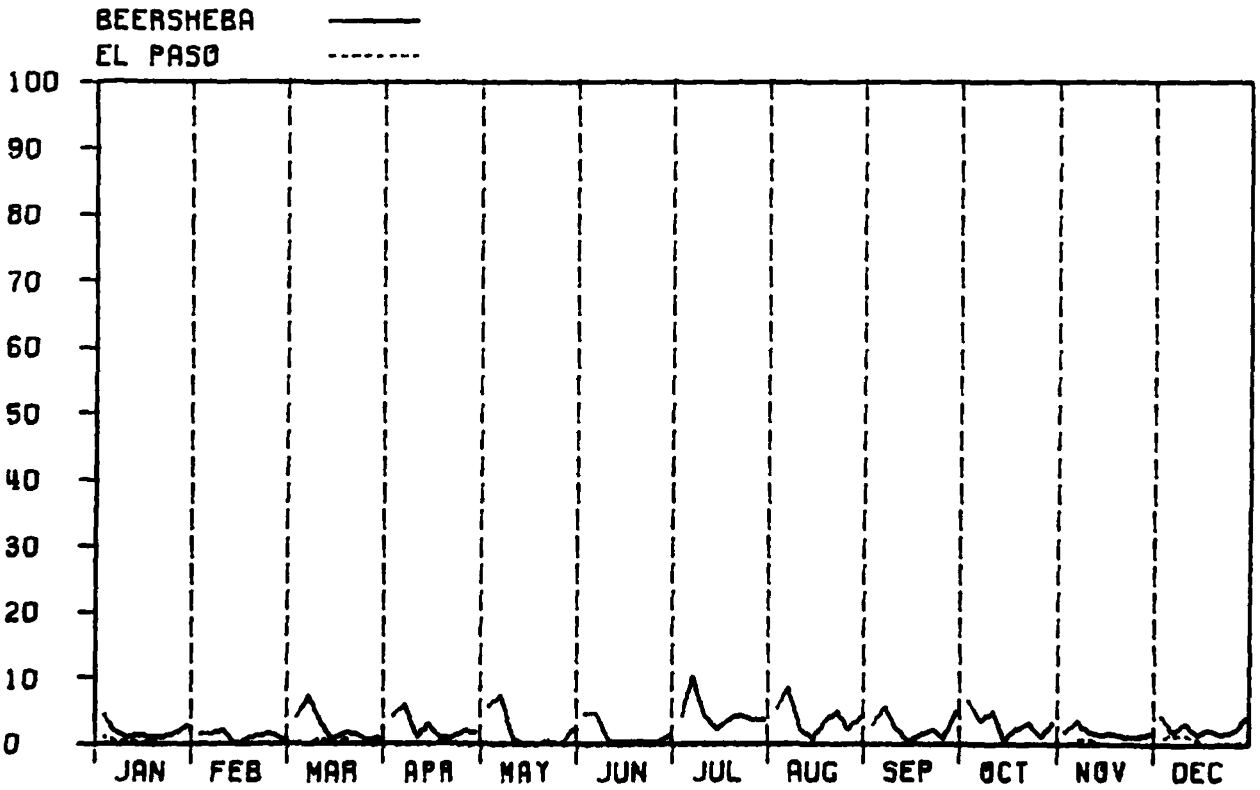
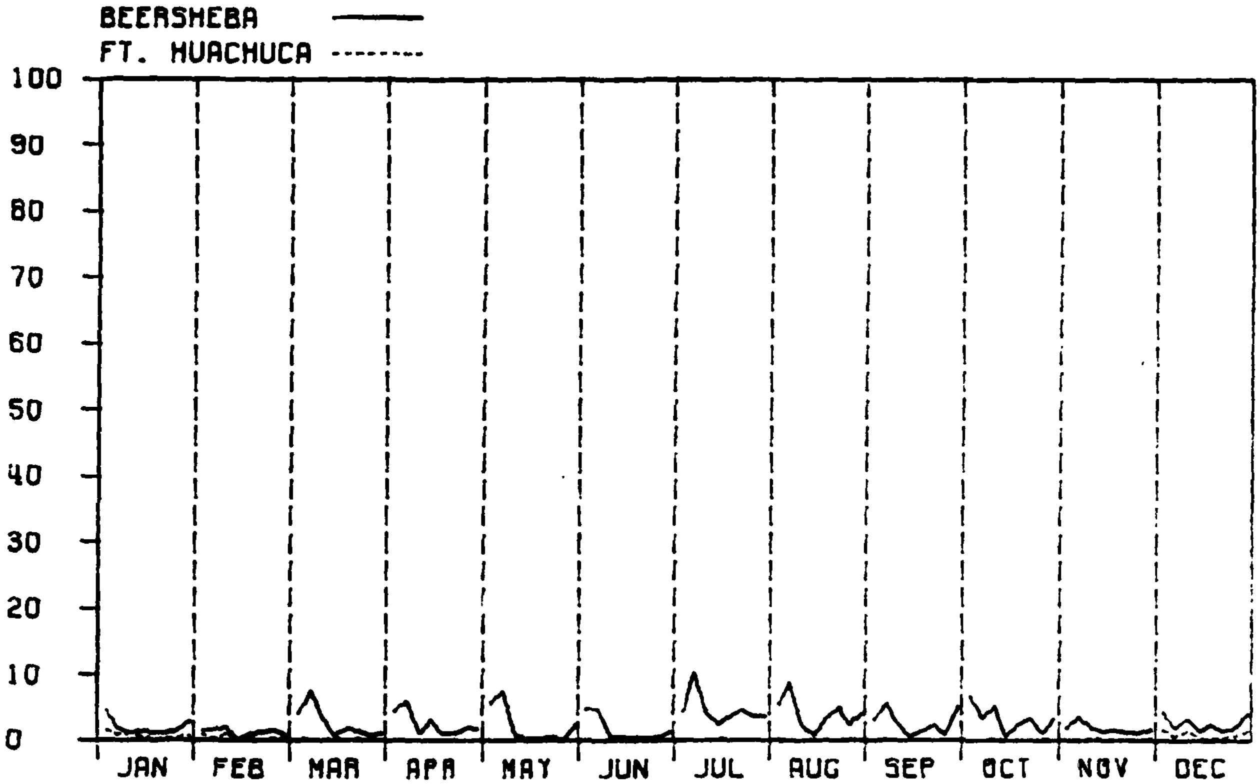



Fig. 15. (Cont'd) VISIBILITY - KM
CLASS (MAX) = 1
FREQUENCY (IN PER CENT), BY 3-HOURLY PERIOD AND BY MONTH



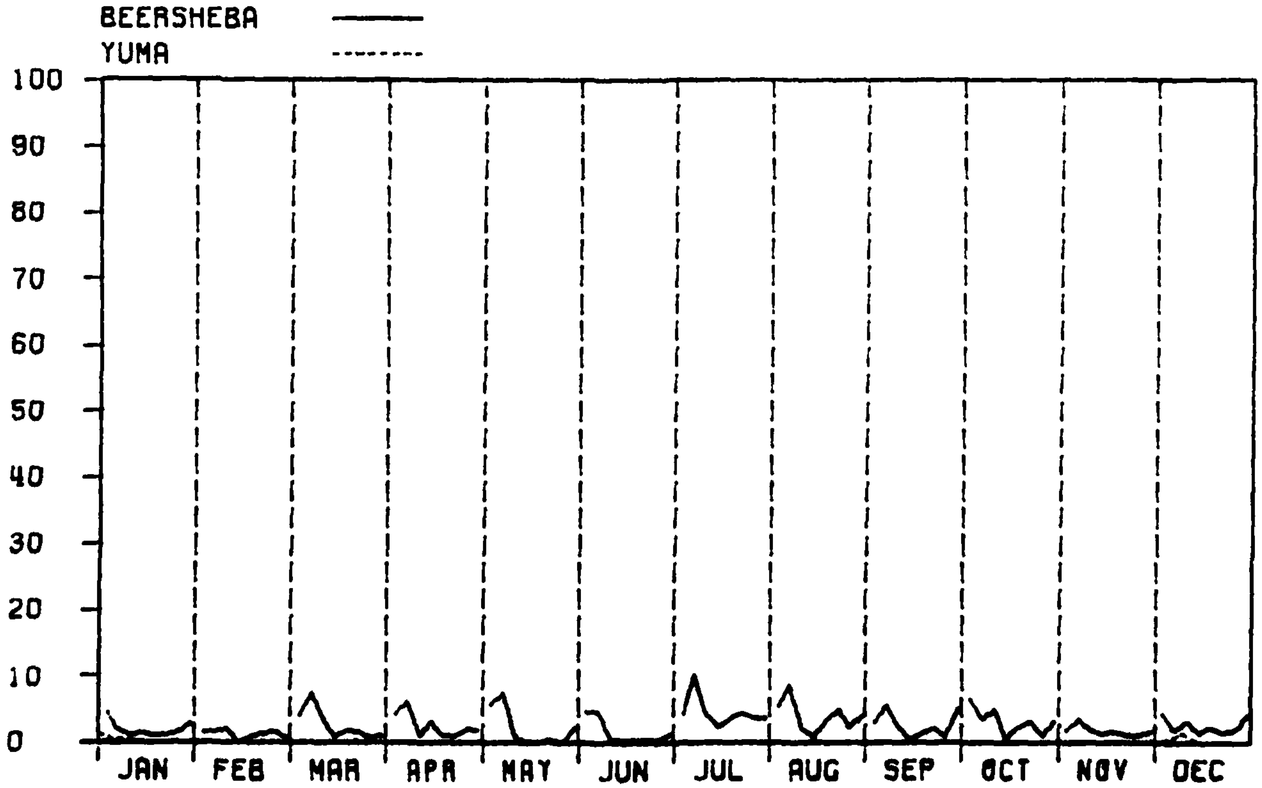
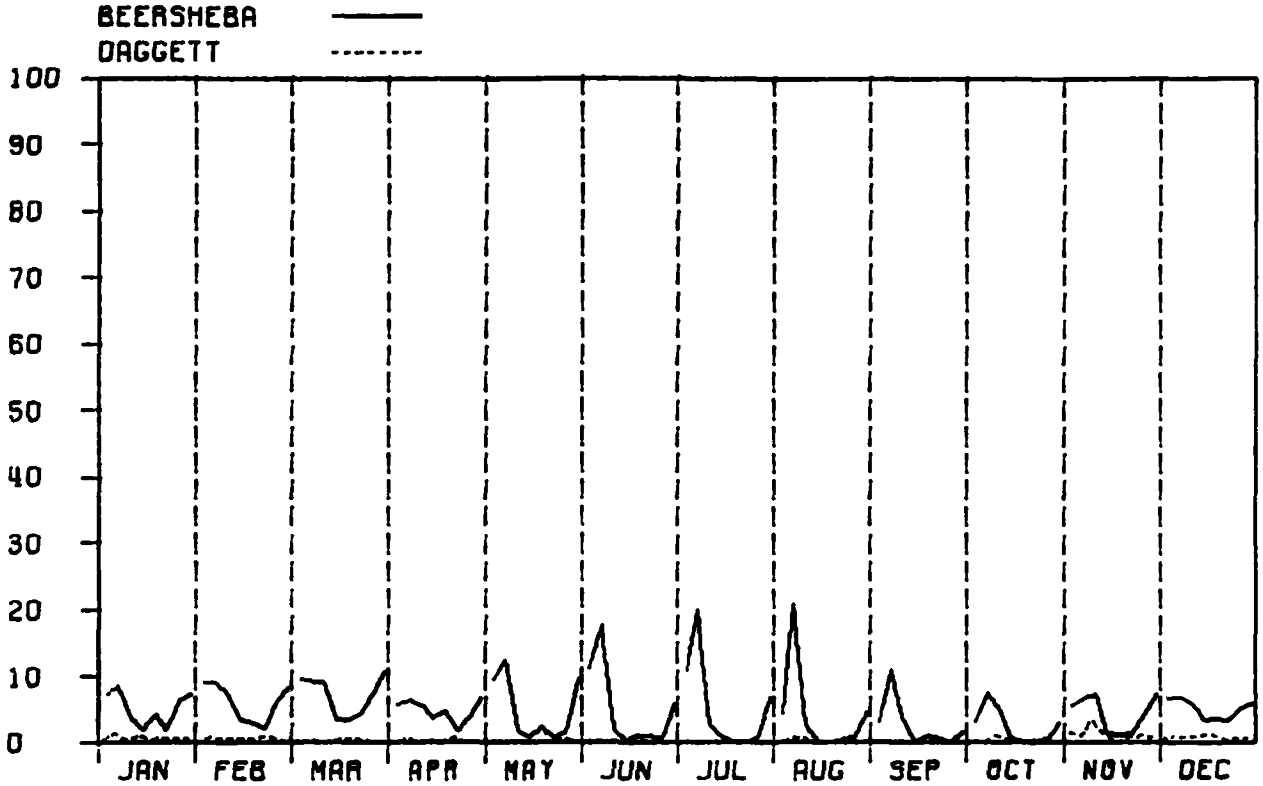



Fig. 15. (Cont'd) VISIBILITY - KM
CLASS (MAX) = 5
FREQUENCY (IN PER CENT). BY 3-HOURLY PERIOD AND BY MONTH



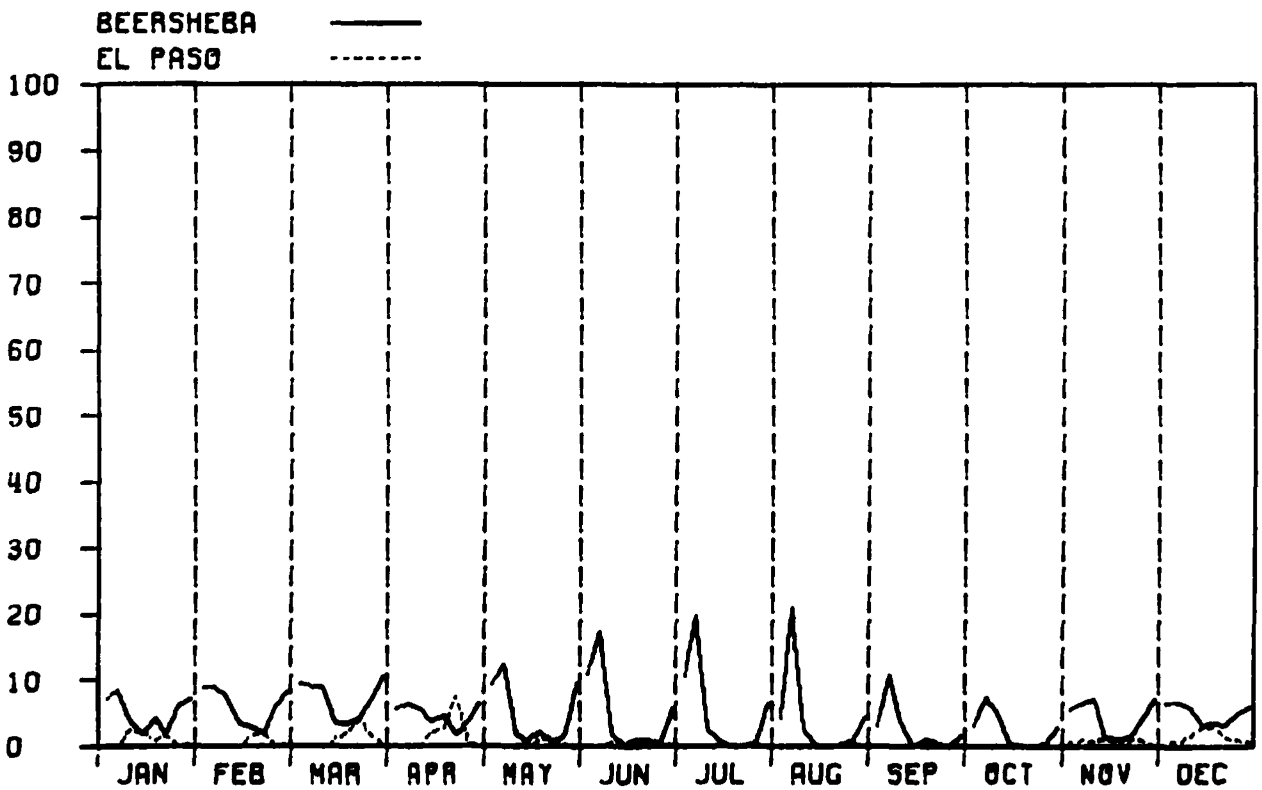
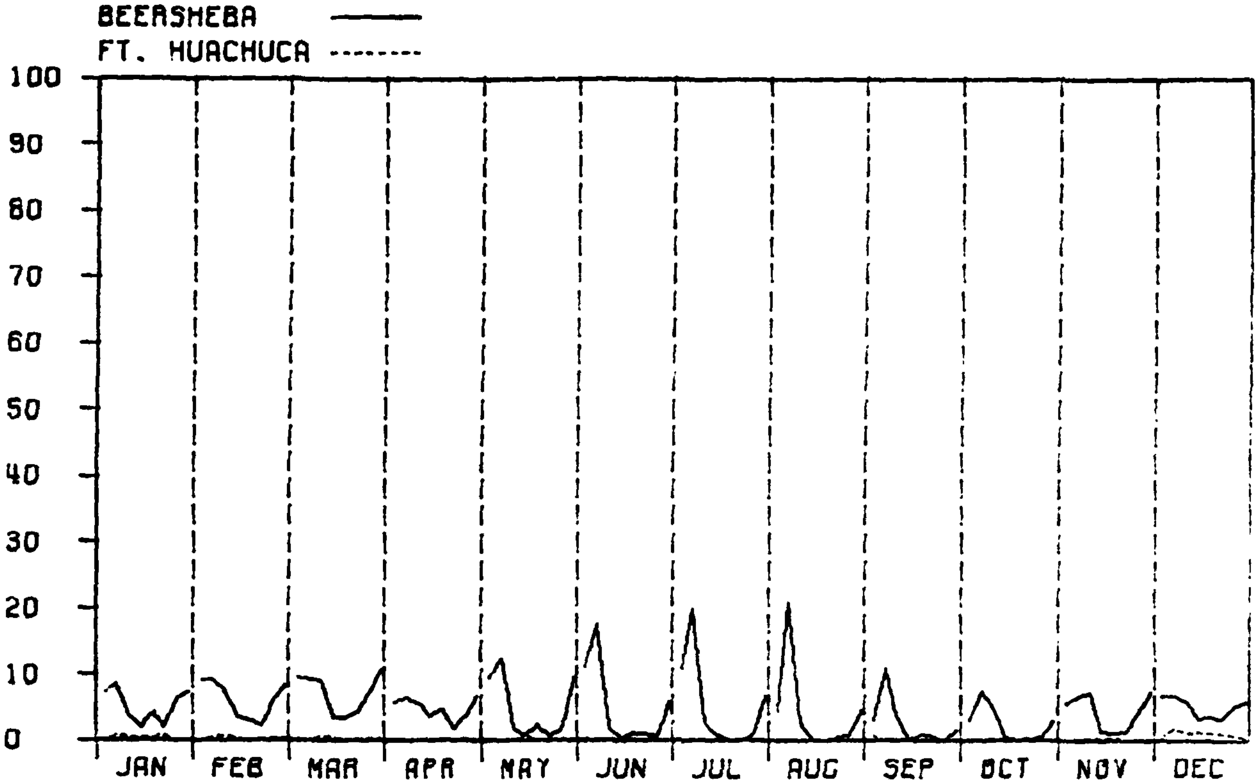



Fig. 15. (Cont'd) VISIBILITY - KM
CLASS (MAX) = 5
FREQUENCY (IN PER CENT). BY 3-HOURLY PERIOD AND BY MONTH



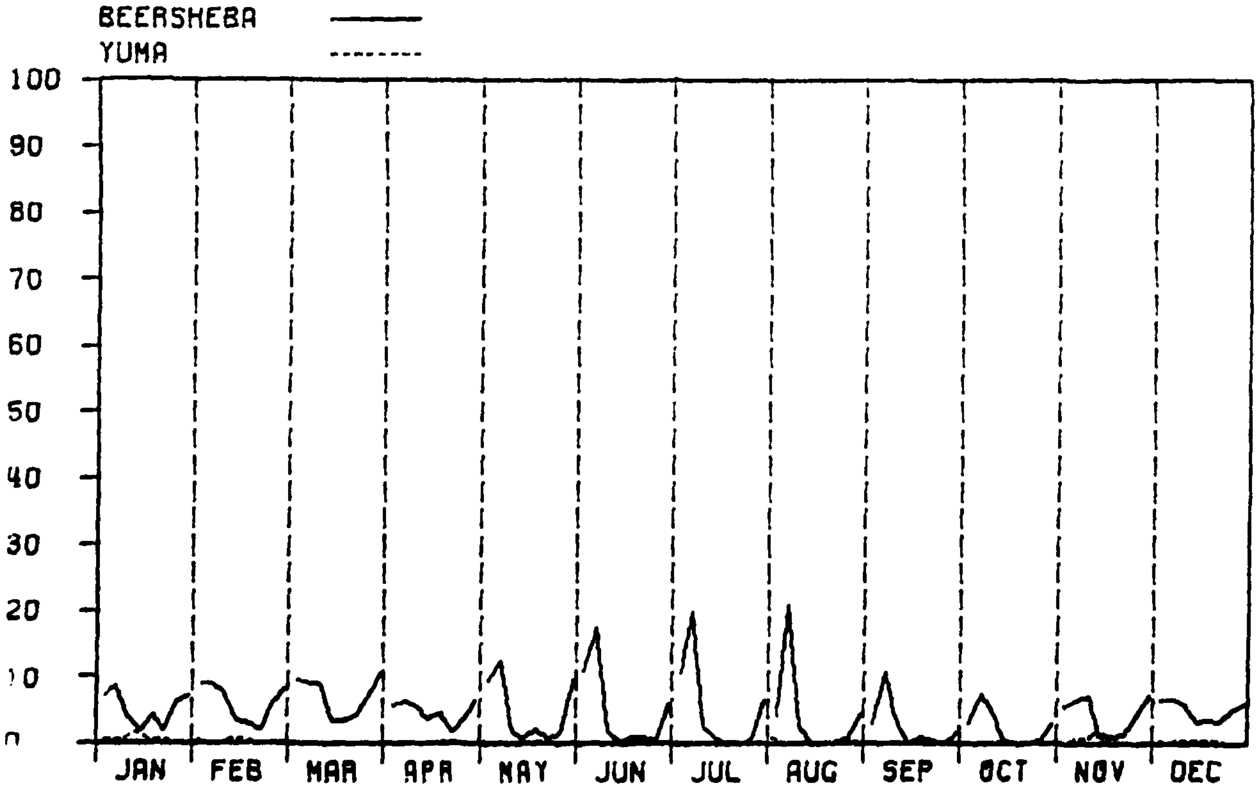
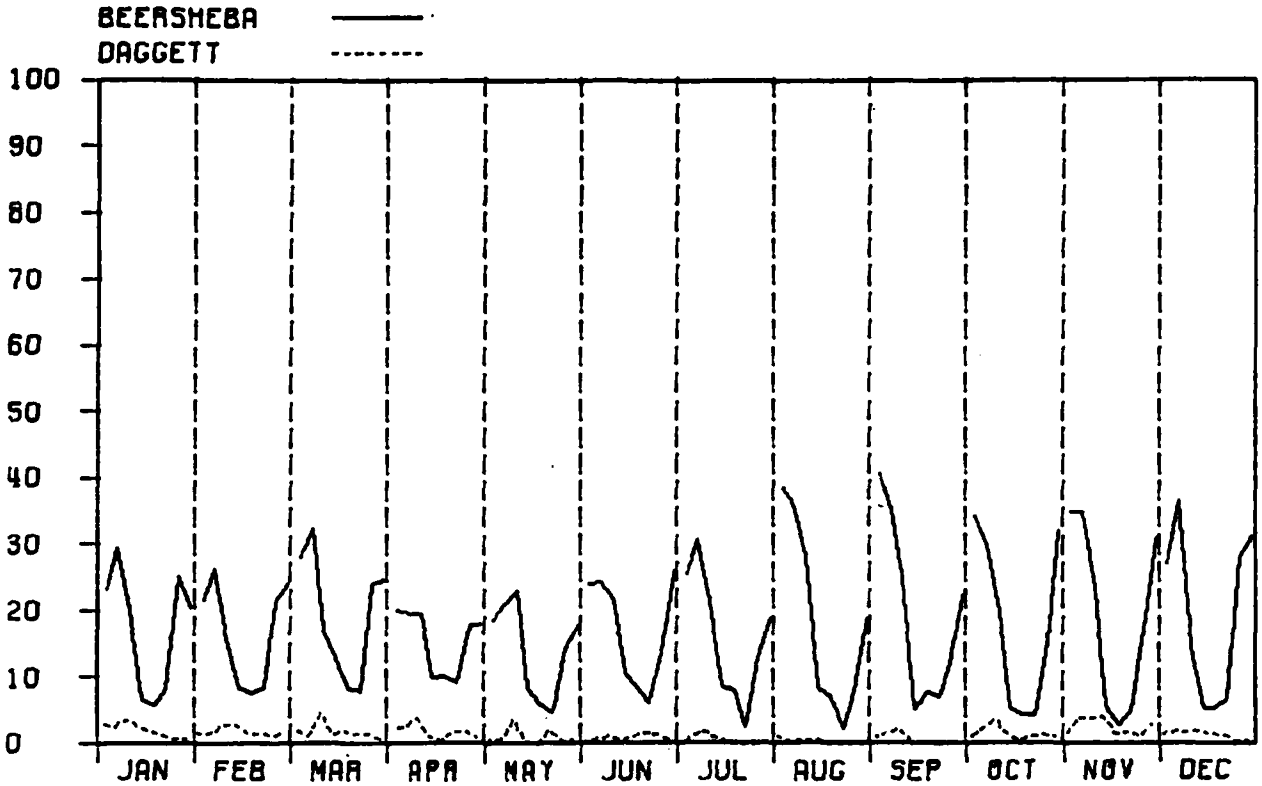



Fig. 15. (Cont'd) VISIBILITY - KM
CLASS (MAX) = 10
FREQUENCY (IN PER CENT). BY 3-HOURLY PERIOD AND BY MONTH



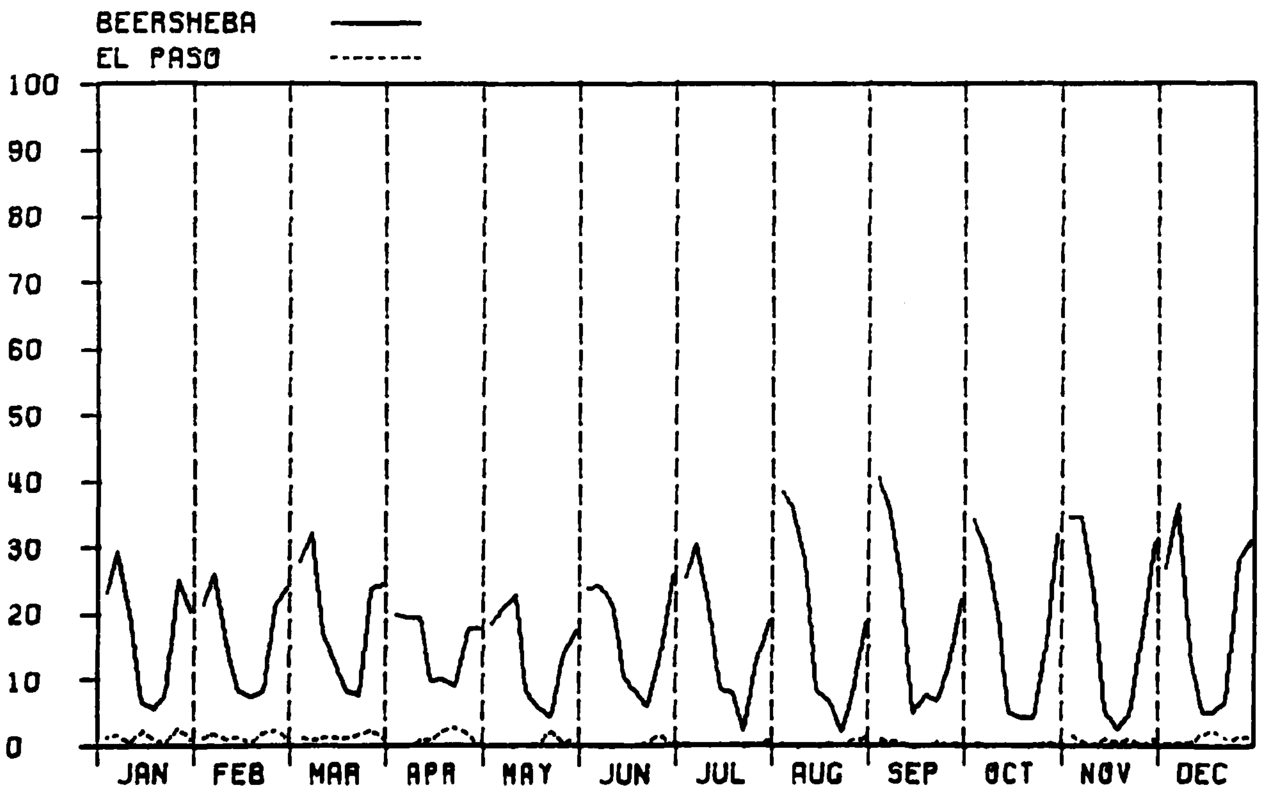
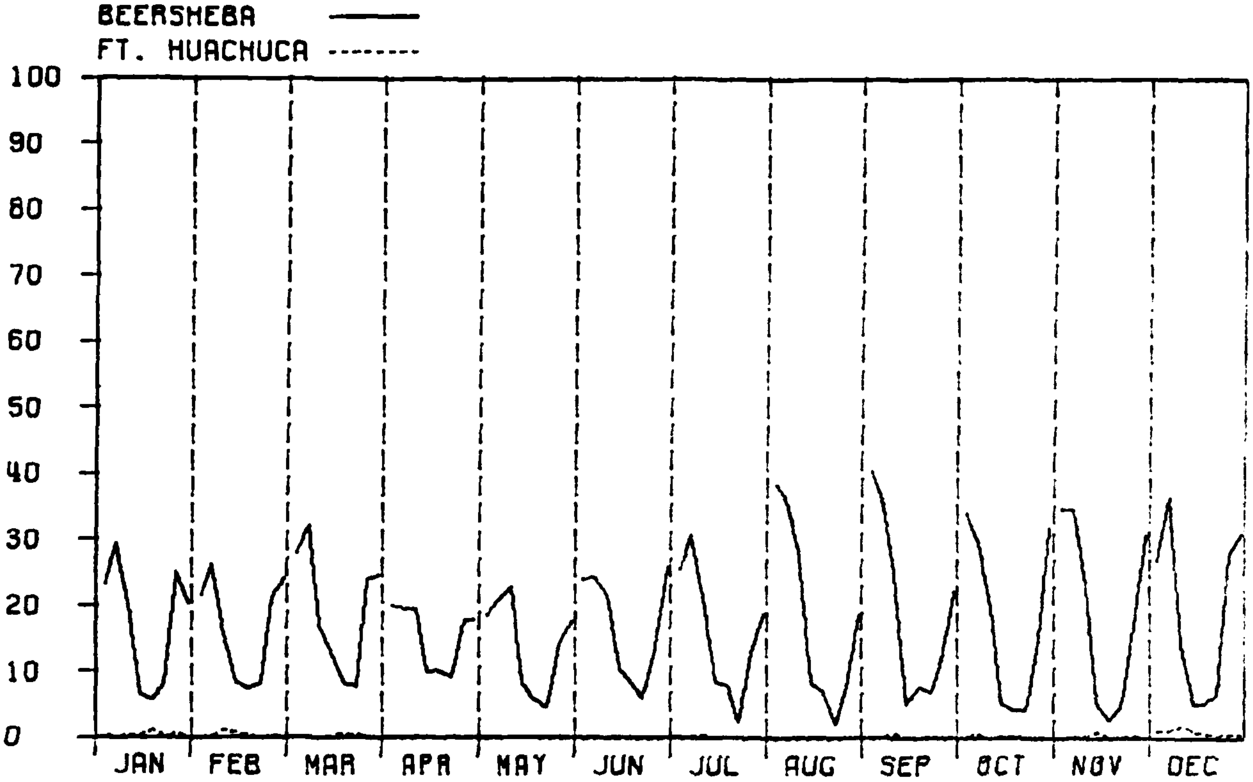



Fig. 15. (Cont'd) VISIBILITY - KM
CLASS (MAX) = 10
FREQUENCY (IN PER CENT), BY 3-HOURLY PERIOD AND BY MONTH



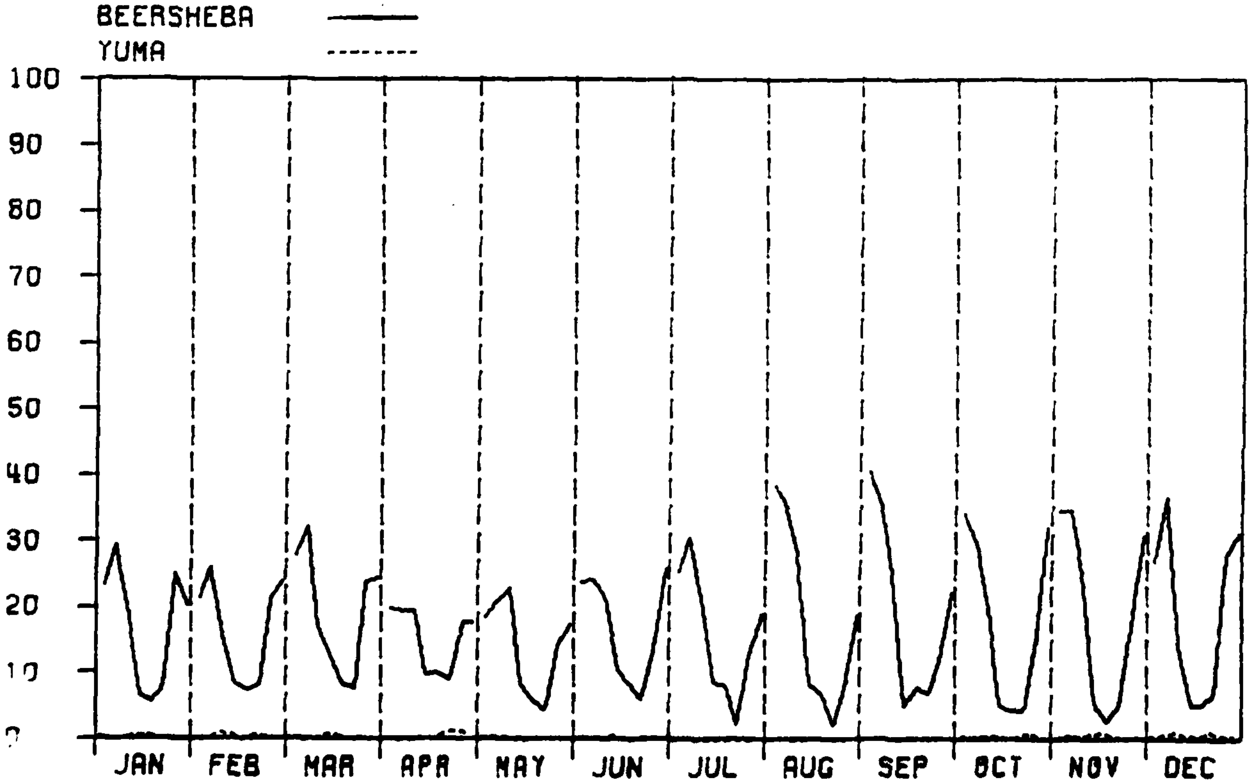
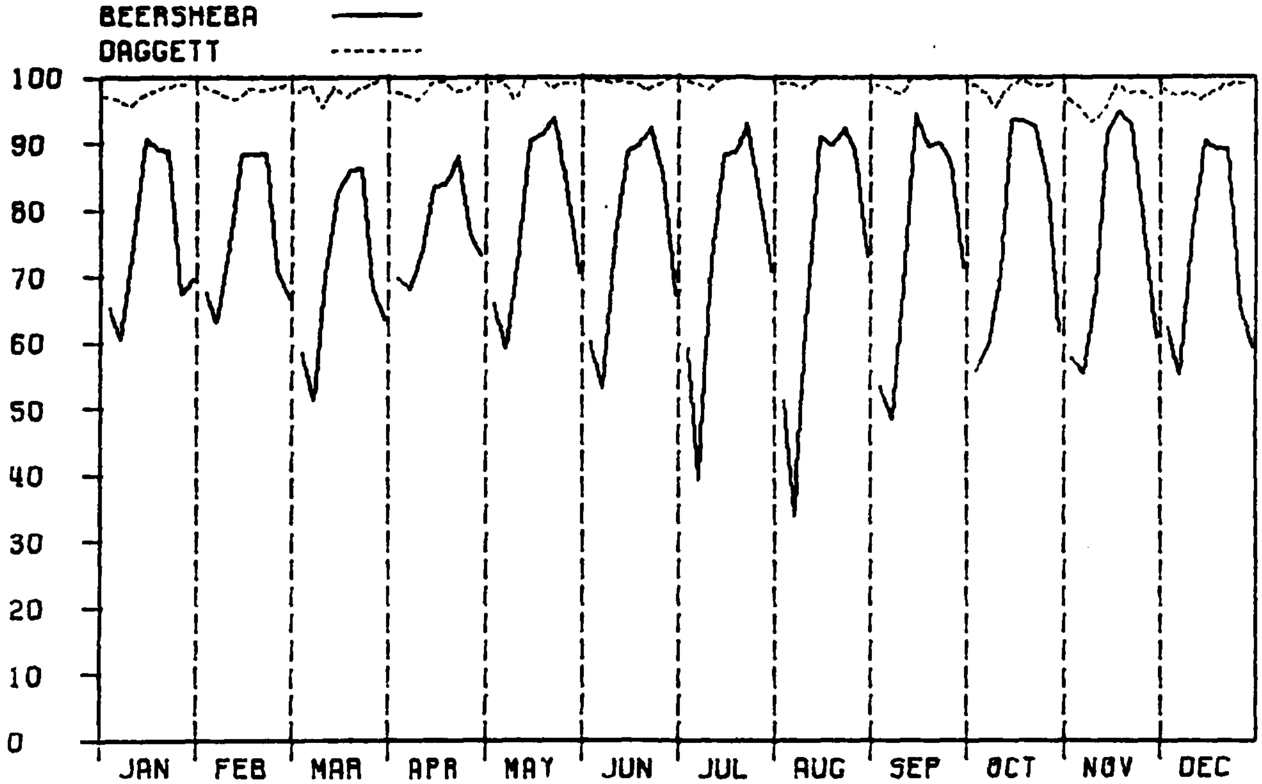



Fig. 15. (Cont'd) VISIBILITY - KM
CLASS (MAX) = >10
FREQUENCY (IN PER CENT), BY 3-HOURLY PERIOD AND BY MONTH



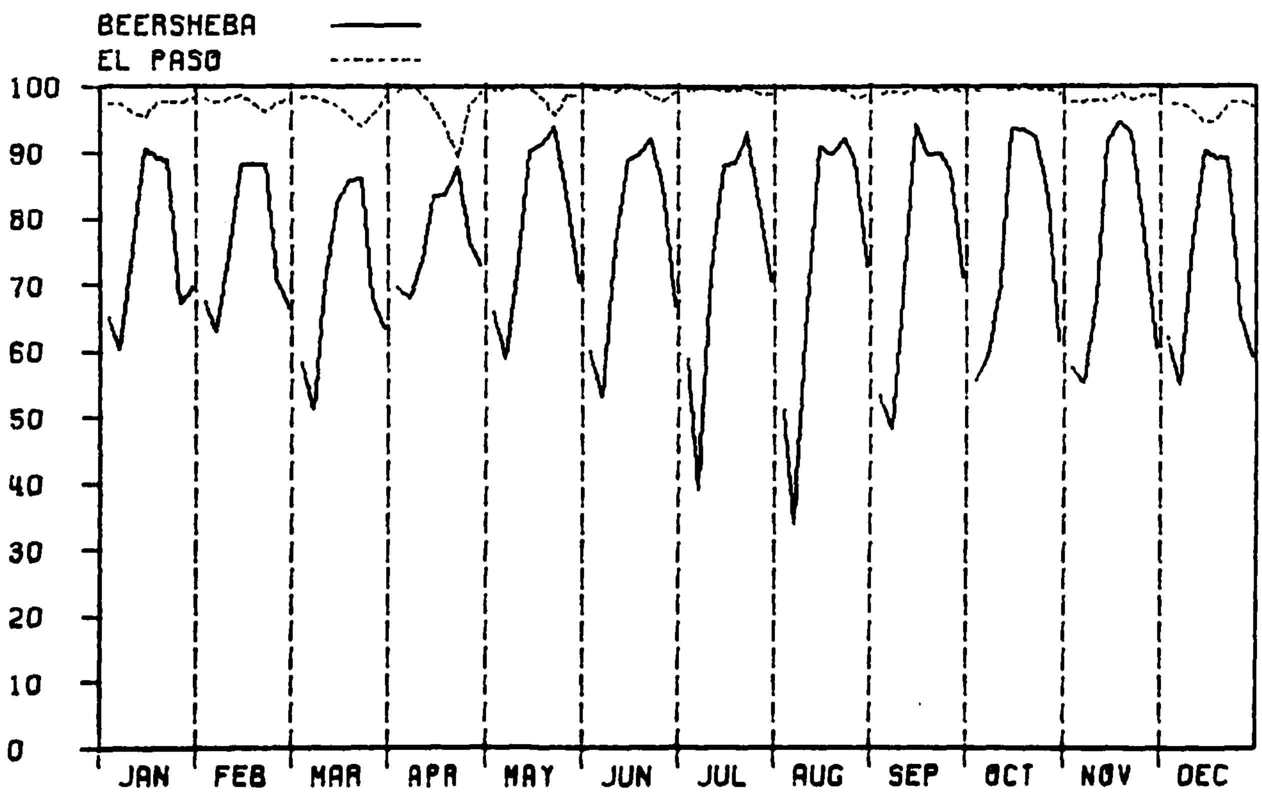
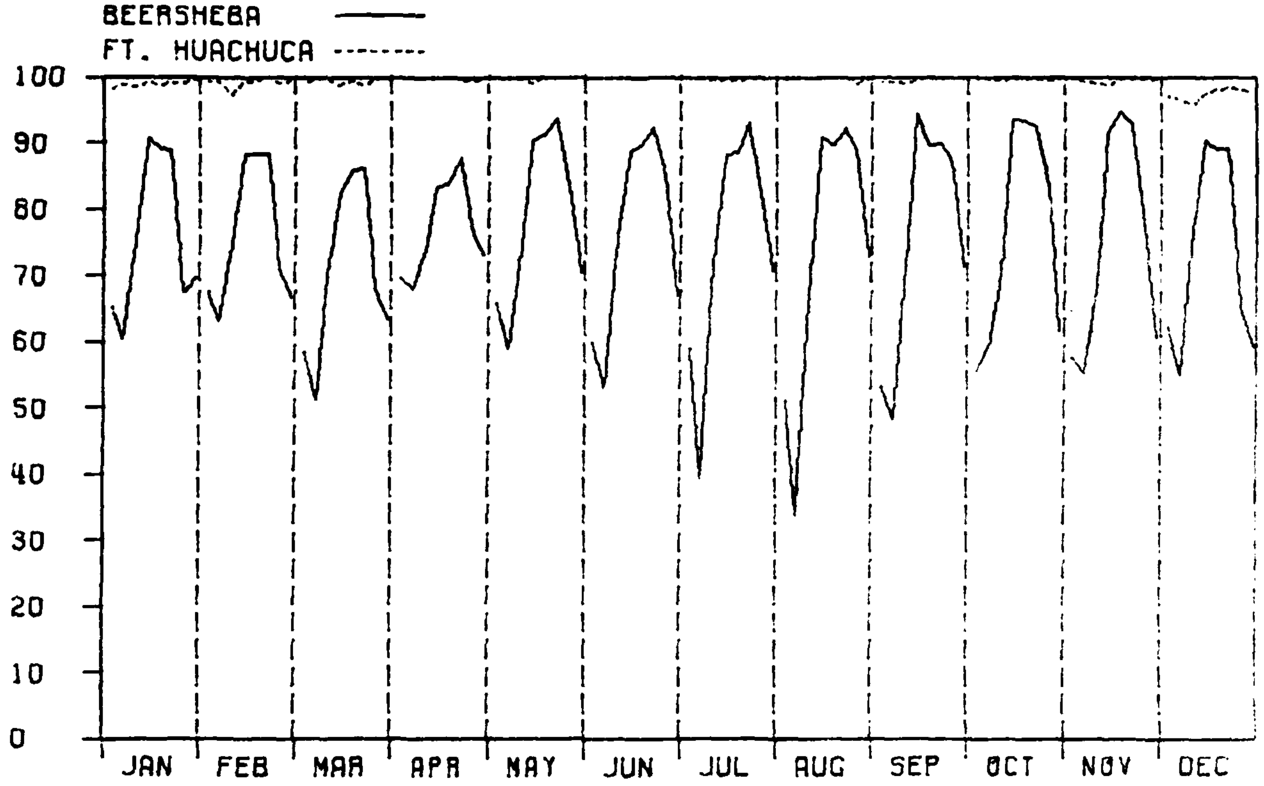



Fig. 15. (Cont'd) VISIBILITY - KM

CLASS (MAX) = >10

FREQUENCY (IN PER CENT), BY 3-HOURLY PERIOD AND BY MONTH



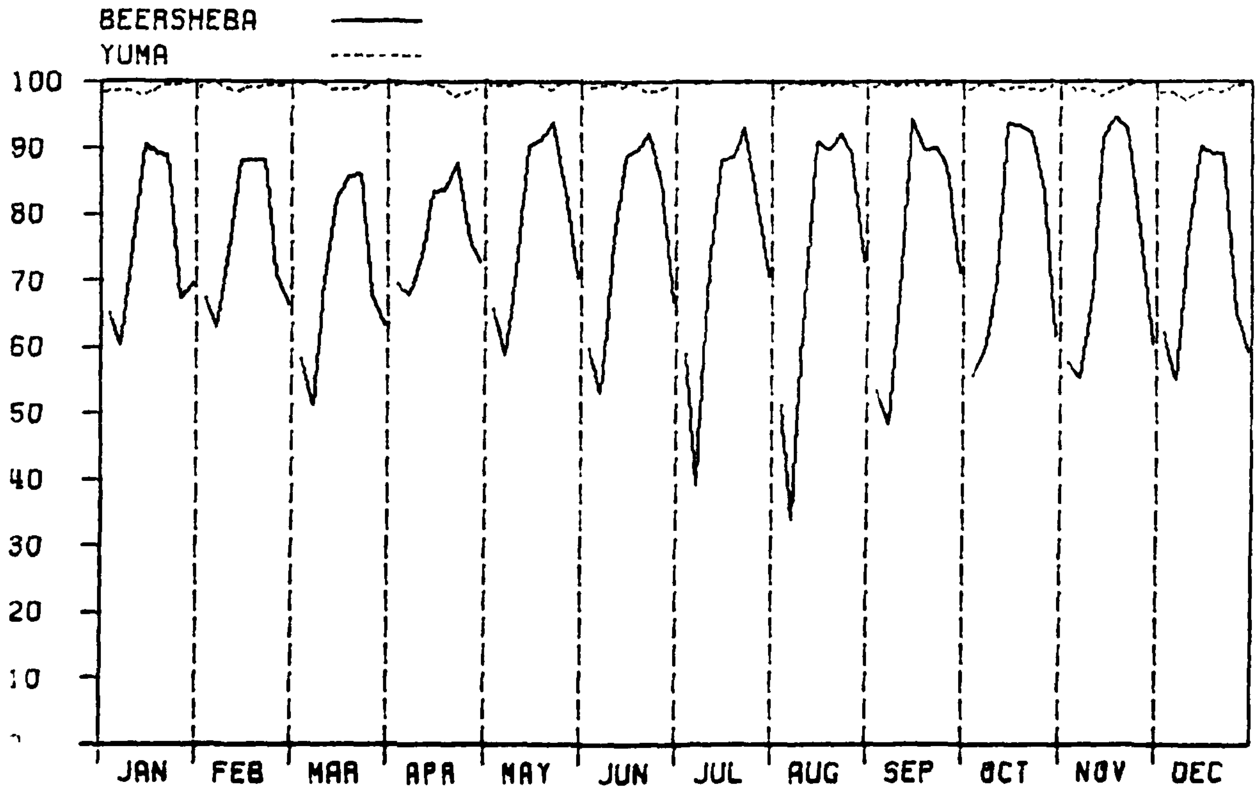



Fig. 16. VISIBILITY - KM
CLASS (MAX) = 1
FREQUENCY (IN PER CENT), BY MONTH

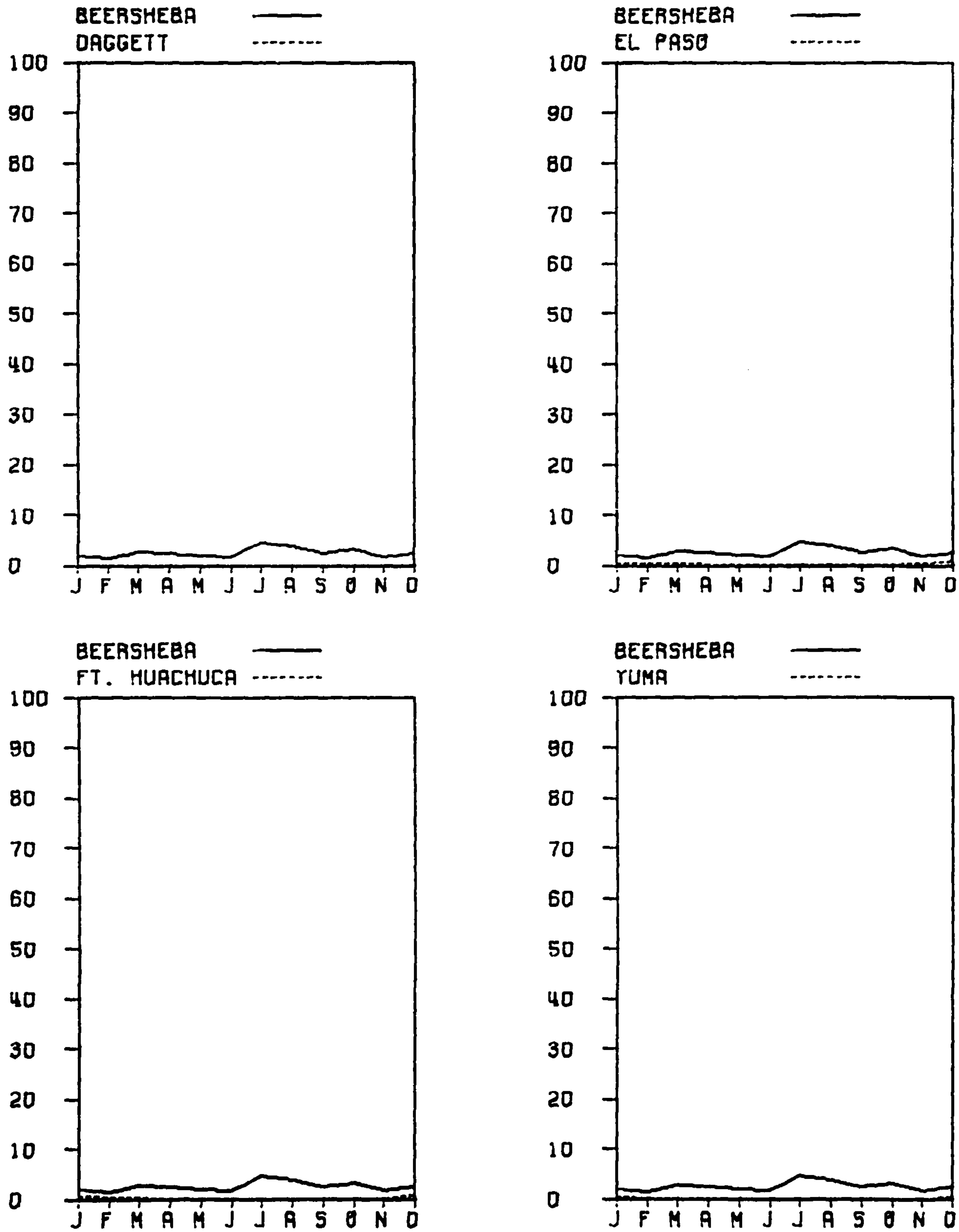


Fig. 16. (Cont'd) VISIBILITY - KM
CLASS (MAX) = 5
FREQUENCY (IN PER CENT), BY MONTH

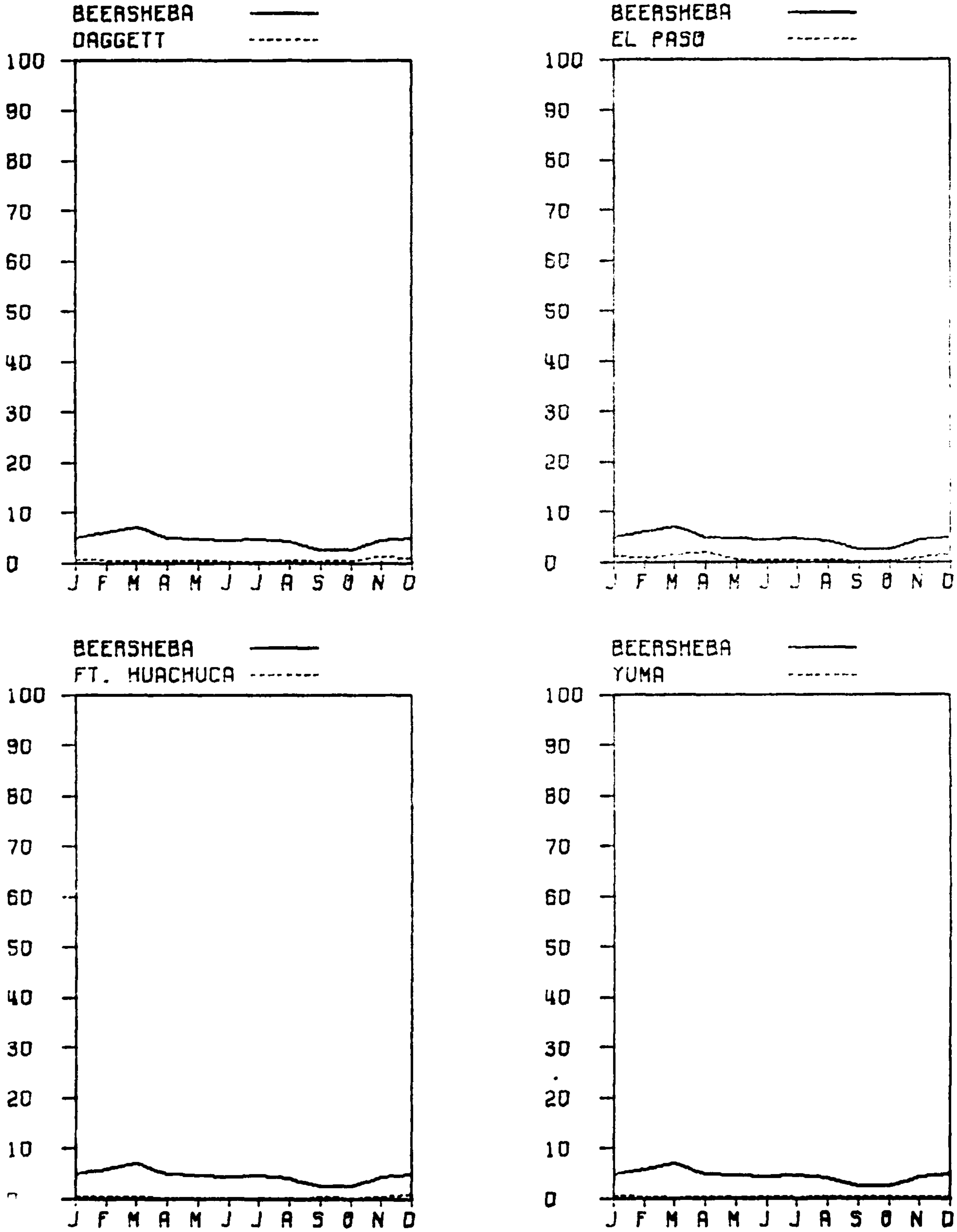


Fig. 16. (Cont'd) VISIBILITY - KM
CLASS (MAX) = 10
FREQUENCY (IN PER CENT), BY MONTH

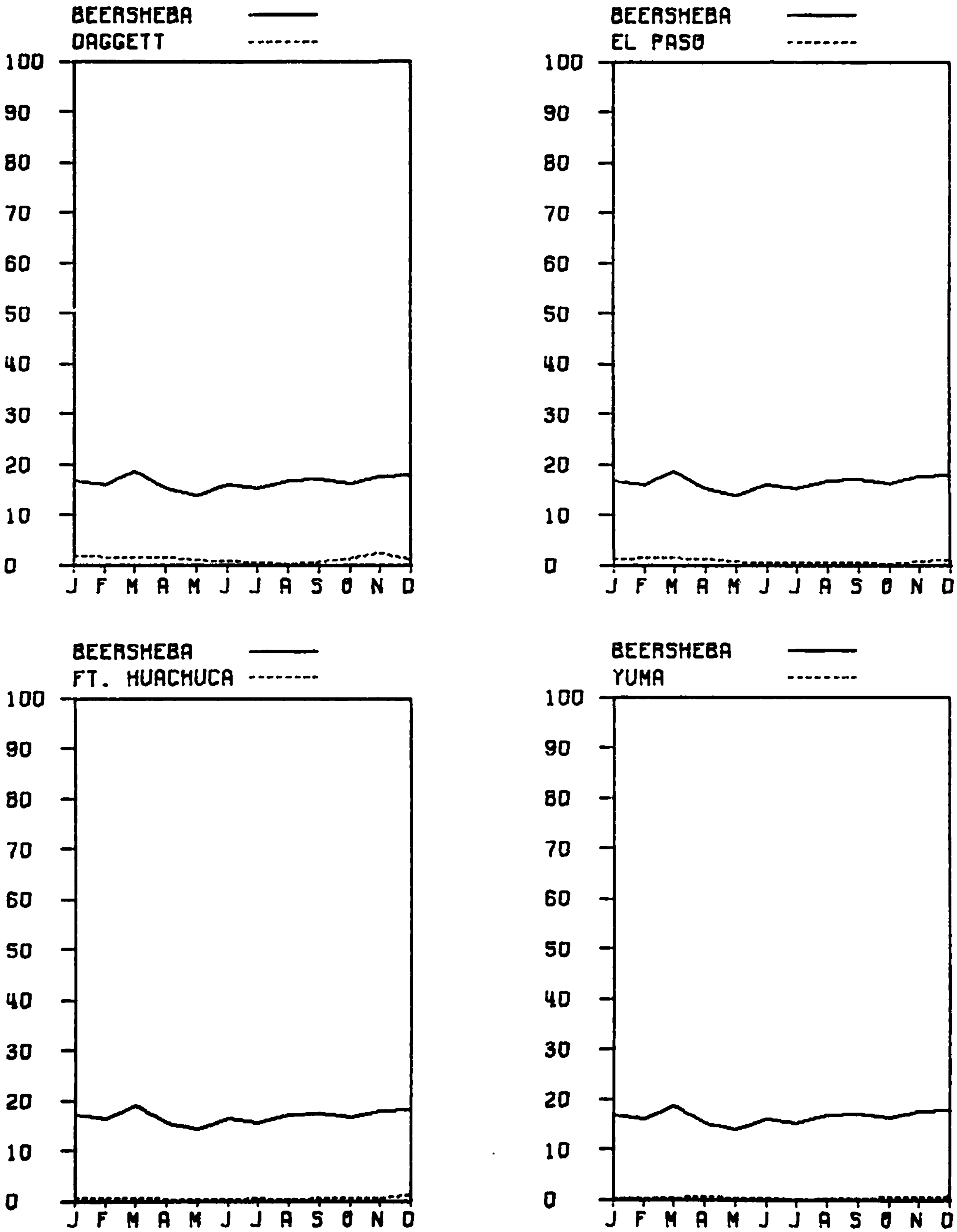
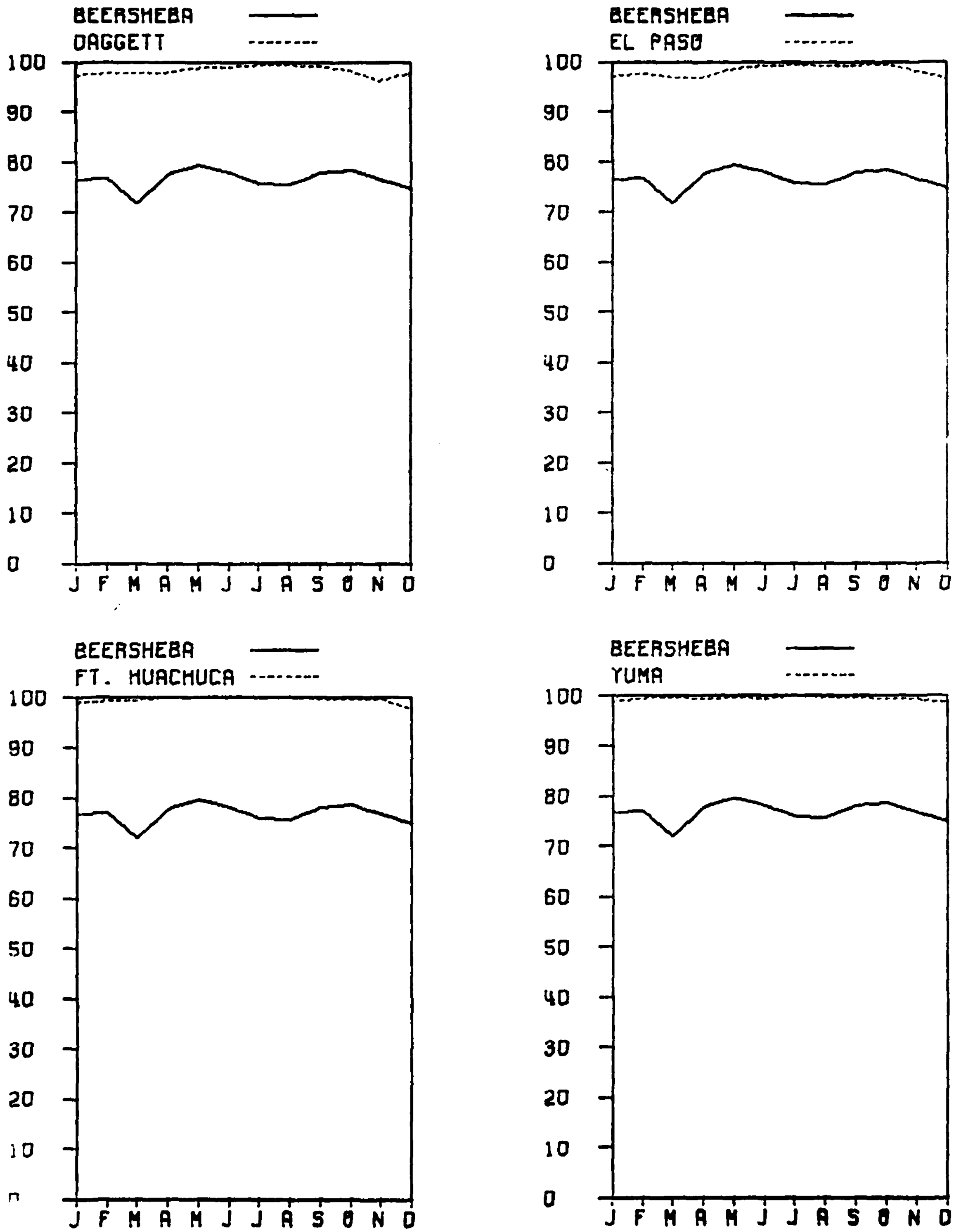


Fig. 16. (Cont'd) VISIBILITY - KM
CLASS (MAX) = >10
FREQUENCY (IN PER CENT), BY MONTH



G. Total Sky Cover (TSC)

Total sky cover refers to the fraction of the sky above the horizon covered by clouds or obscuring phenomena. In the Synoptic Code, which applies to the Beersheba data, the TSC is given in eighths. In the Airways Code, which applies to the U.S. stations, the TSC is given in tenths. The TSC was put into four classes as given below, in agreement with standard procedures.

| Class | Synoptic Codes (eighths) | Airways Code (tenths) |
|---|---|---|
| Clear | 0 | 0 |
| Scattered | 1-4 | 1-5 |
| Broken | 5-7 | 6-9 |
| Overcast | 8 | 10 |

As seen in Fig. 17 for U.S. stations clear skies occur more frequently in the evening hours and least frequently during the daylight hours. This is true also of Beersheba except during the summer months, especially, when there is a strong 0500 IST minimum and a 1700 to 2000 IST maximum. As a result, the scattered and broken classes tend to show the opposite daily variations, high frequency during the day, and low during the night, except as noted above for Beersheba.

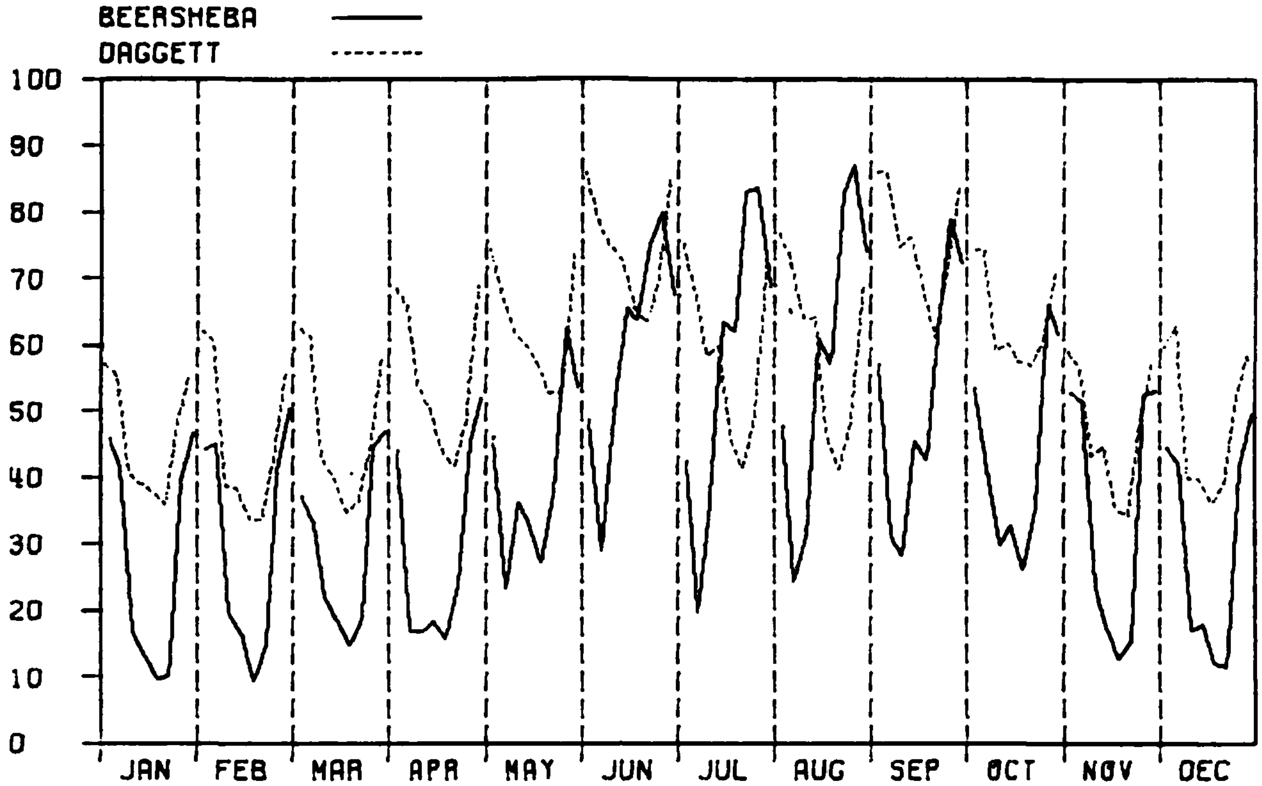
Of interest in the overcast class is the early evening peak at Ft. Huachuca during July and August. Presumably this is associated with the late afternoon and early evening showers and thunderstorms discussed in the climate summary. Beersheba shows a peak in overcast skies at 0500 IST nine of

the twelve months, the sharpest peaks occurring during the summer months. The most likely explanation is morning fog.

Fig. 18 shows that the patterns of monthly frequencies for the clear, scattered and broken classes are similar for the U.S. stations. The frequency of clear skies tends to increase during the warm months at Beersheba while there is a characteristic drop in July and August at the U.S. stations. Opposing patterns are seen in the scattered and broken classes.

The frequency of overcast skies is typically lower at Beersheba than at the U.S. stations. The reason for the sharp rise in frequency of overcast skies during July and August at Ft. Huachuca was explained above. Based on Fig. 18 the station that best matches Beersheba is Daggett.

Fig. 17. TOTAL SKY COVER
CLASS = CLEAR
FREQUENCY (IN PER CENT). BY 3-HOURLY PERIOD AND BY MONTH



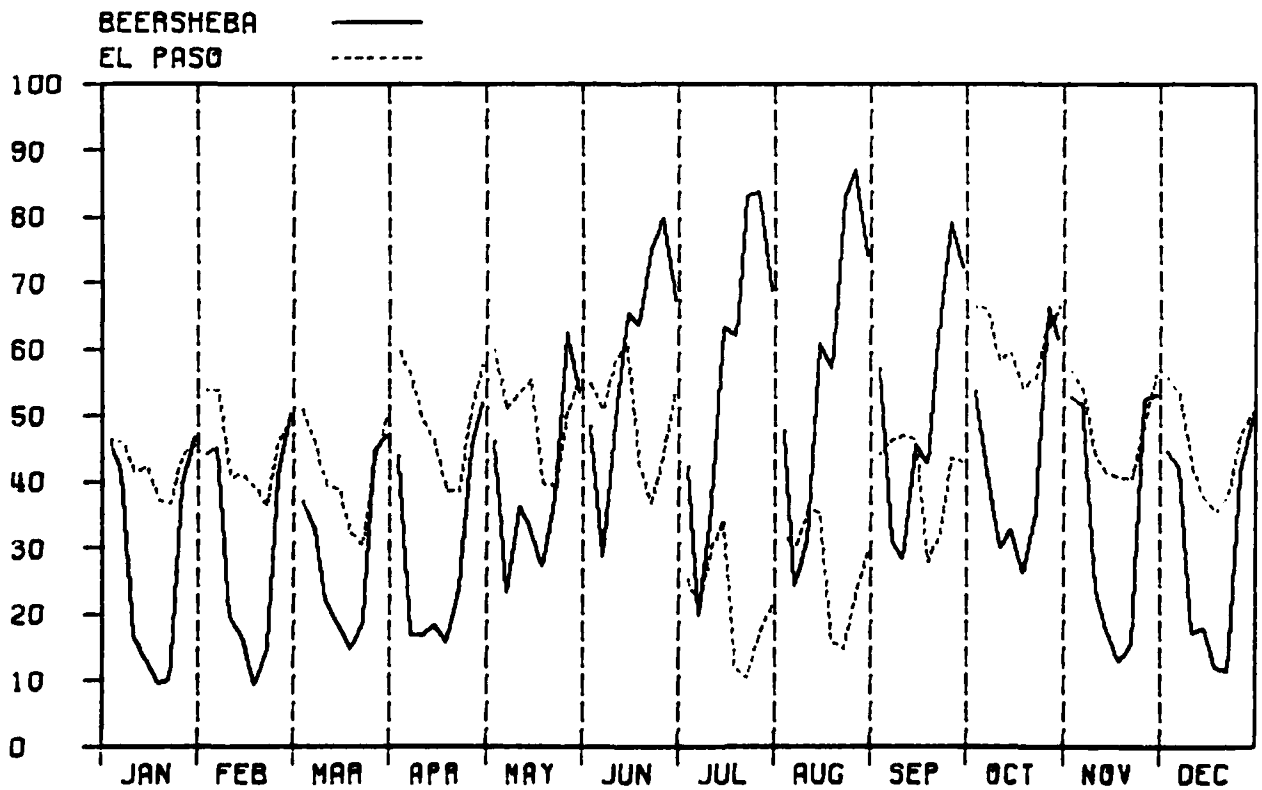
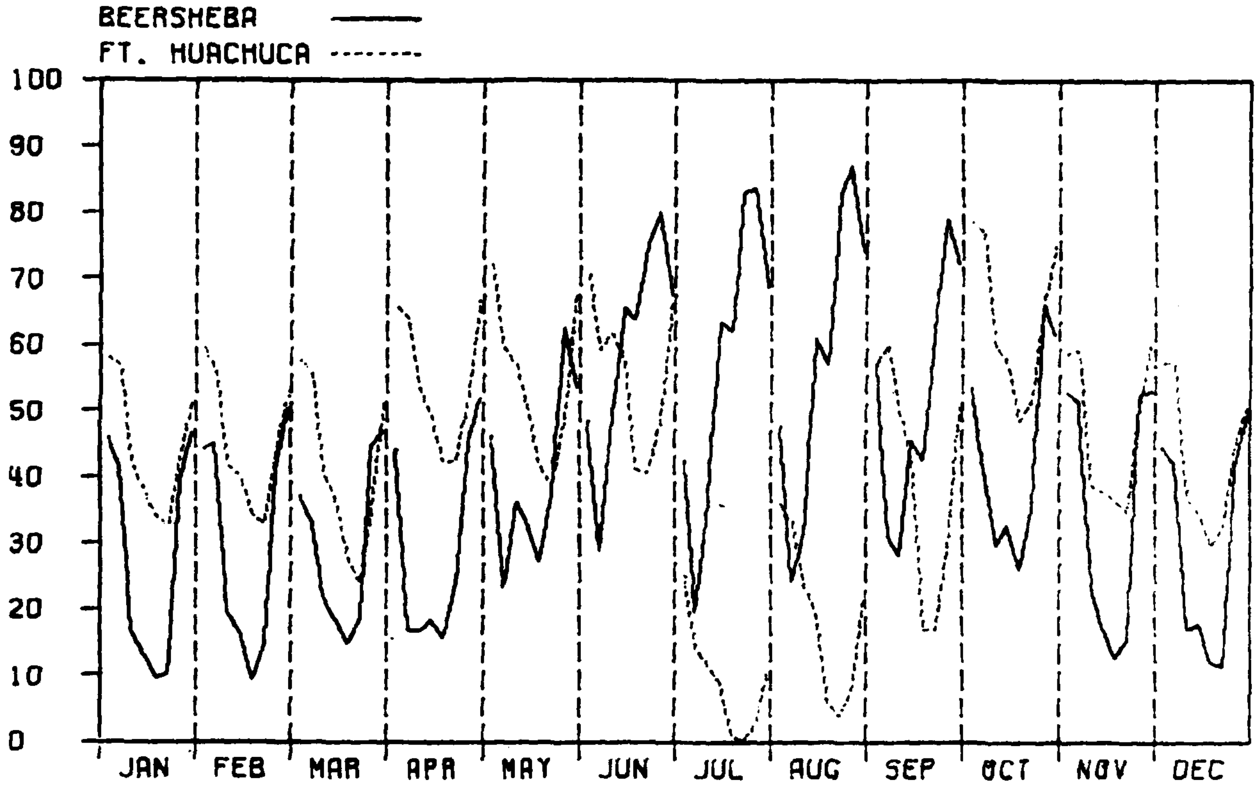



Fig. 17. (Cont'd) TOTAL SKY COVER
CLASS = CLEAR
FREQUENCY (IN PER CENT), BY 3-HOURLY PERIOD AND BY MONTH



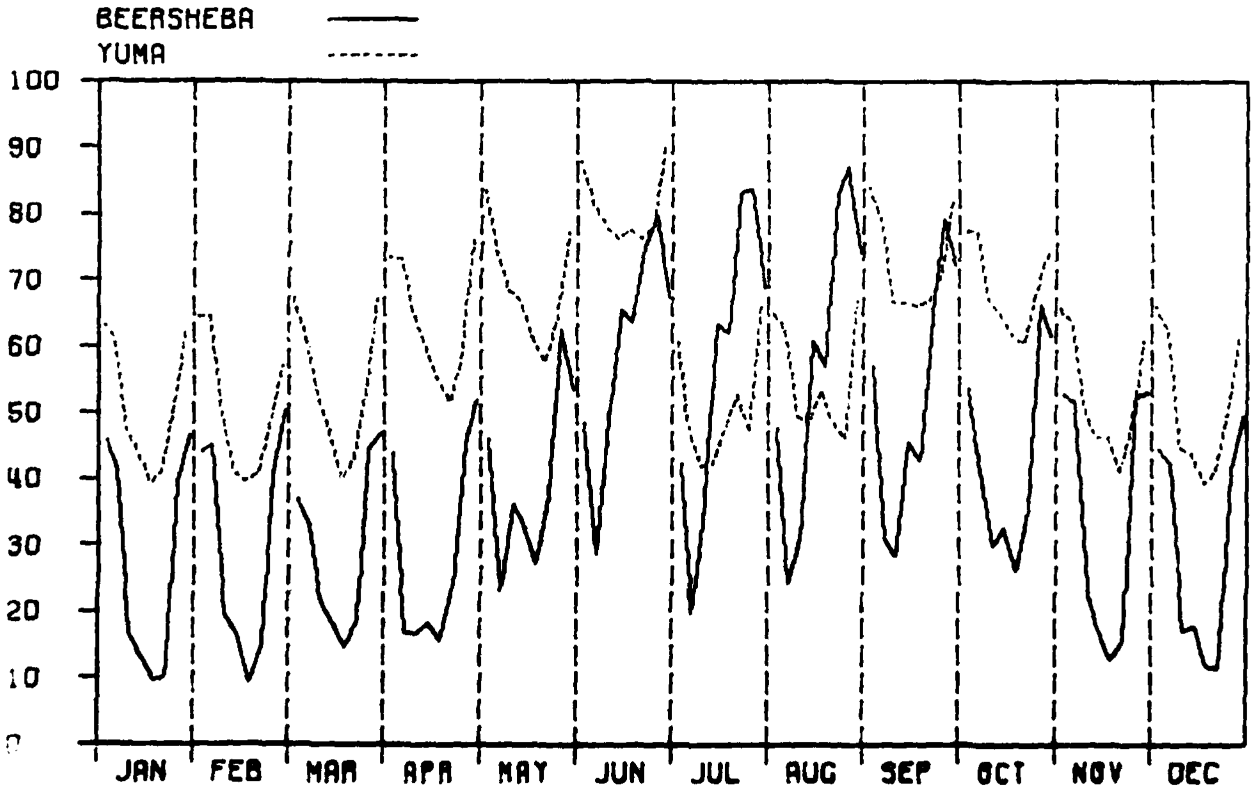
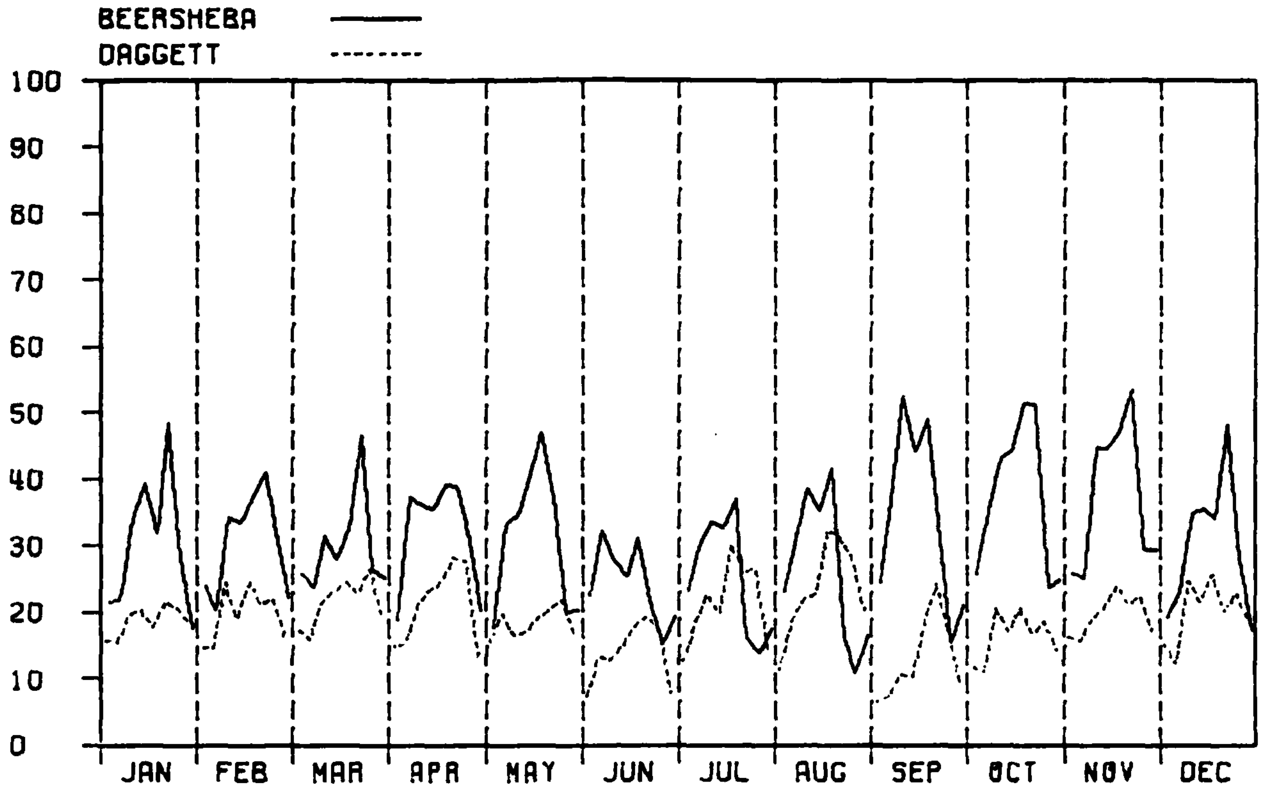



Fig. 17. (Cont'd) TOTAL SKY COVER

CLASS = SCATTERED

FREQUENCY (IN PER CENT). BY 3-HOURLY PERIOD AND BY MONTH



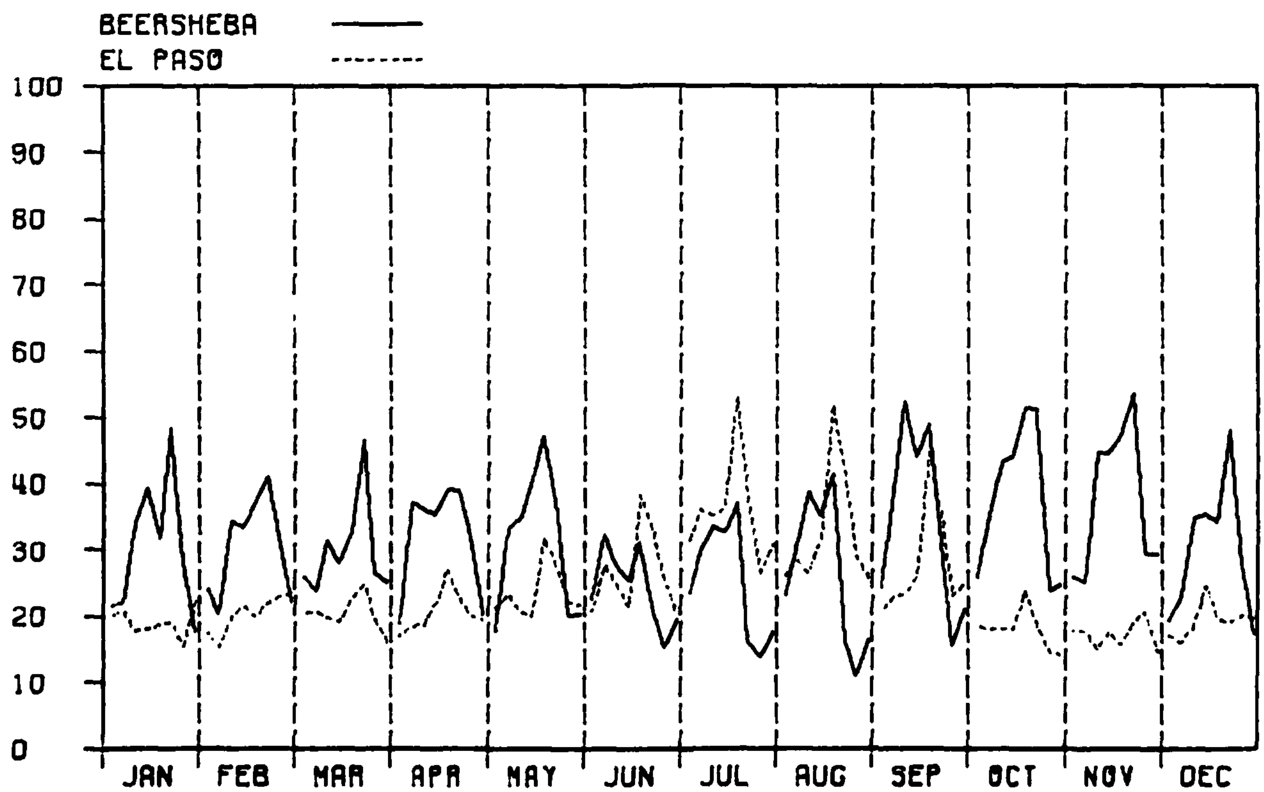
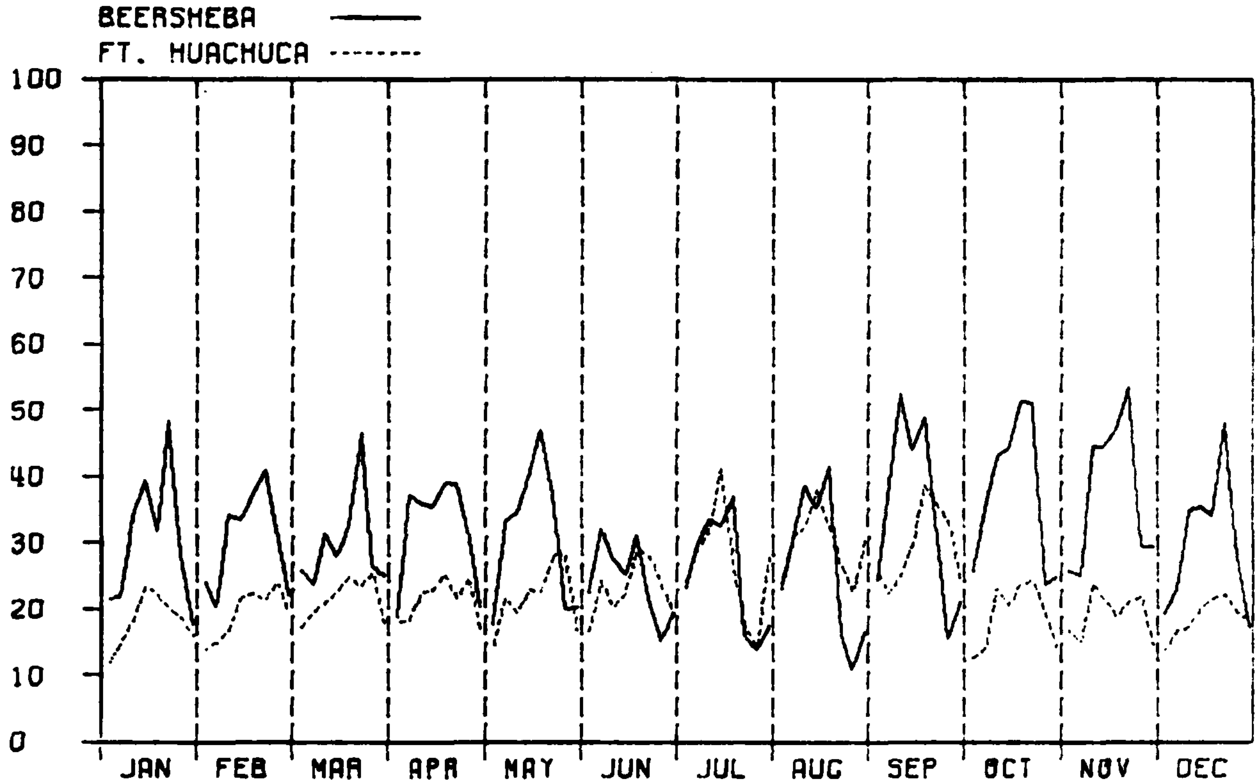



Fig. 17. (Cont'd) TOTAL SKY COVER
CLASS = SCATTERED
FREQUENCY (IN PER CENT). BY 3-HOURLY PERIOD AND BY MONTH



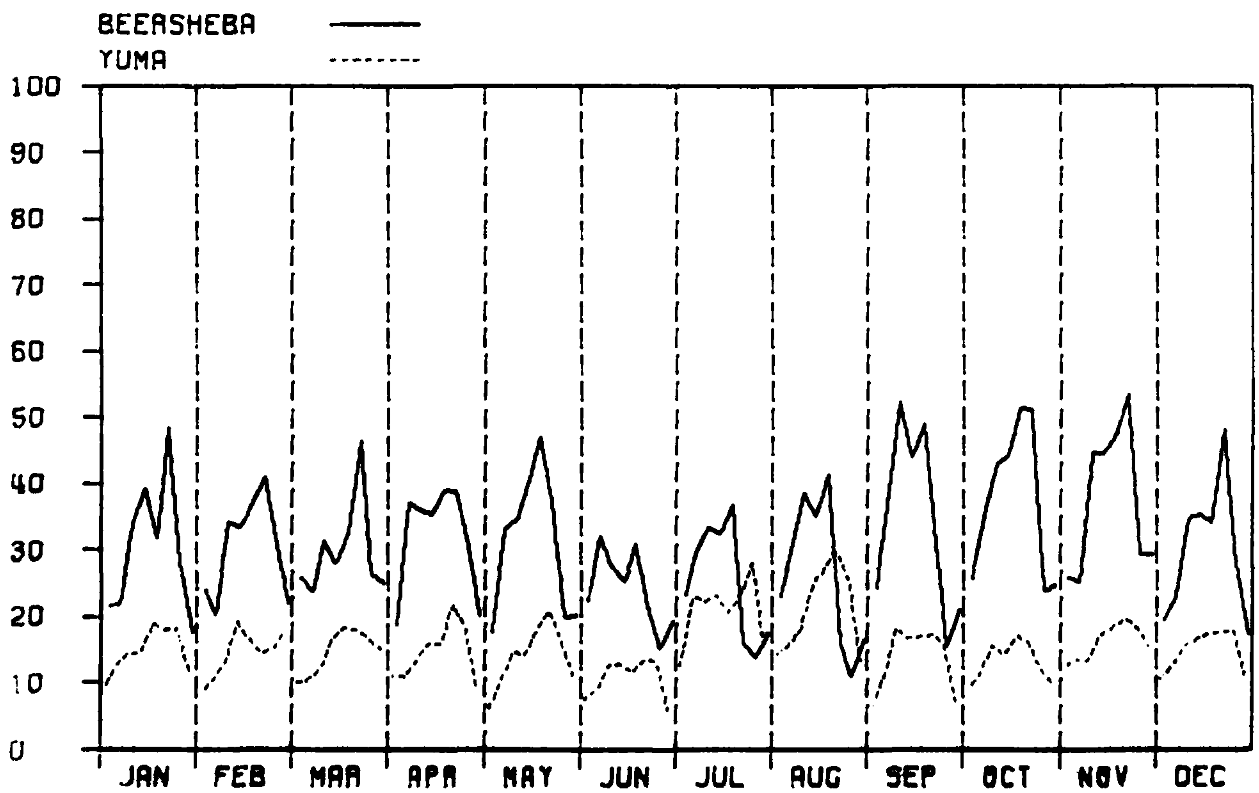
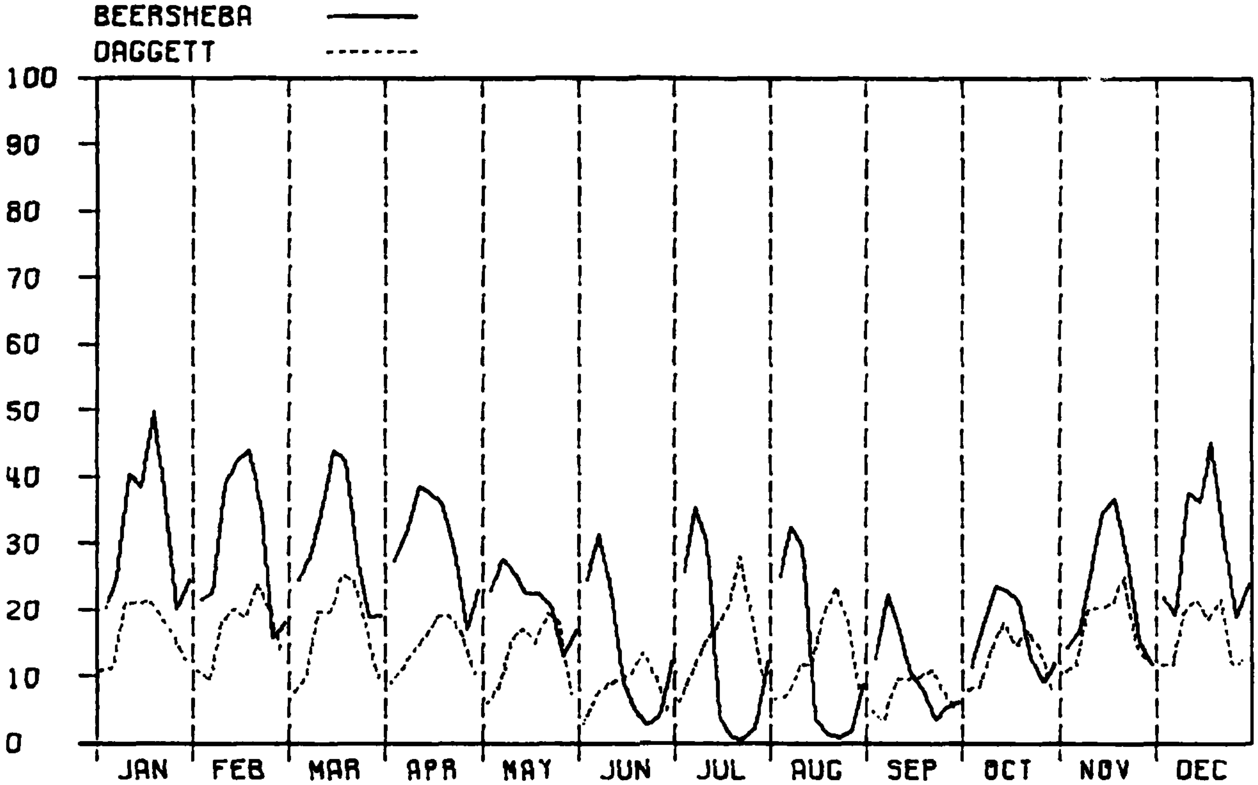



Fig. 17. (Cont'd) TOTAL SKY COVER

CLASS = BROKEN

FREQUENCY (IN PER CENT). BY 3-HOURLY PERIOD AND BY MONTH



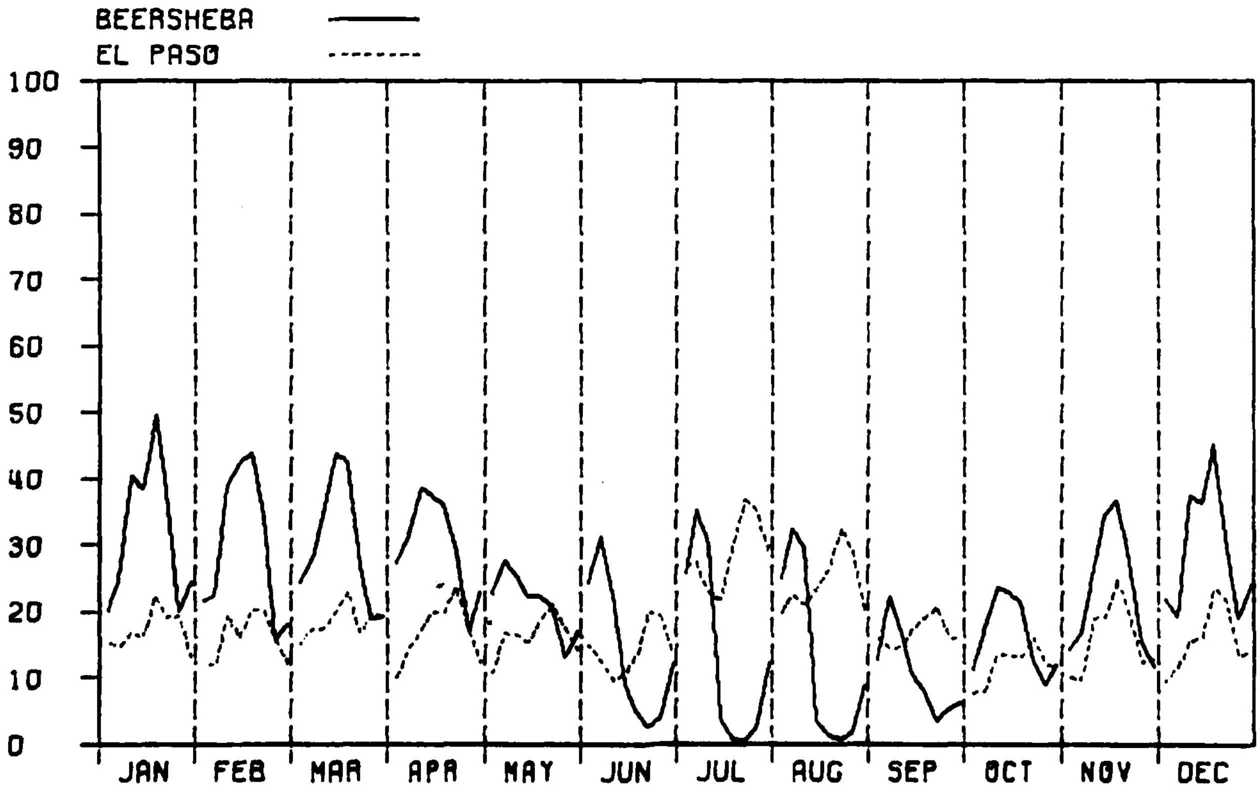
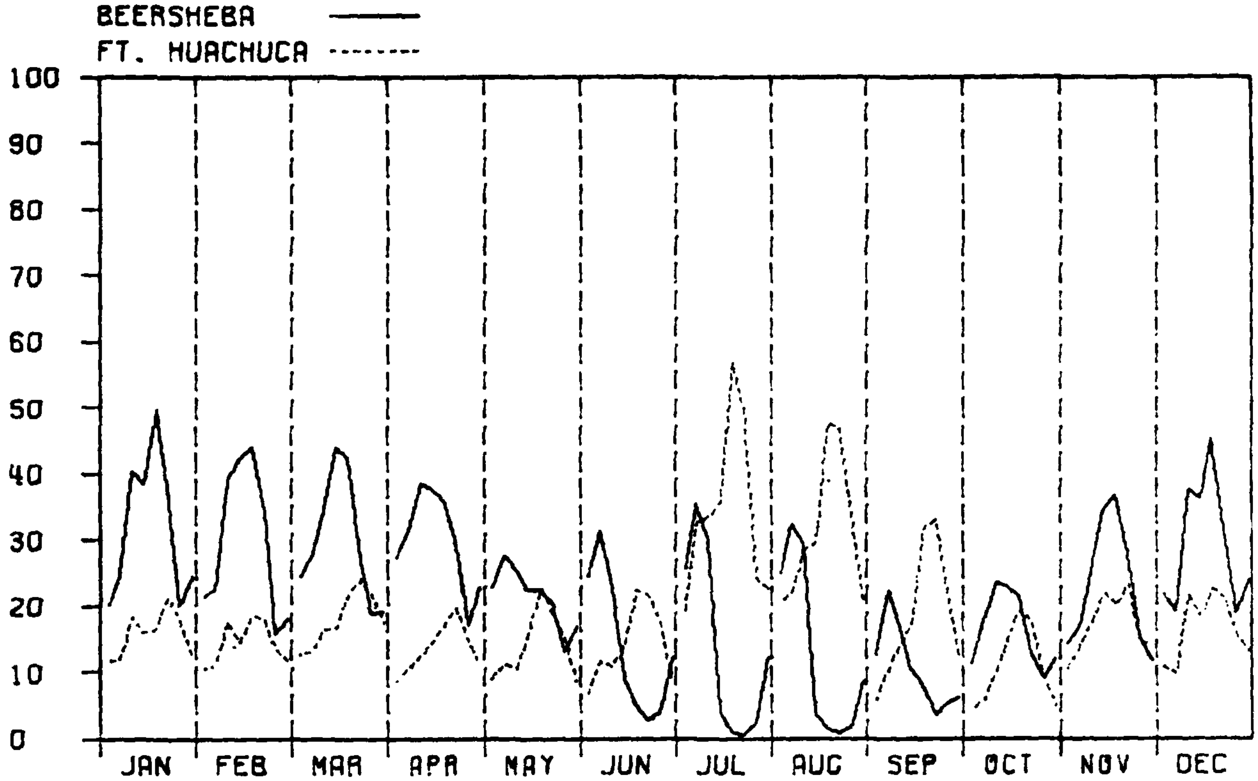



Fig. 17. (Cont'd) TOTAL SKY COVER
CLASS = BROKEN
FREQUENCY (IN PER CENT). BY 3-HOURLY PERIOD AND BY MONTH



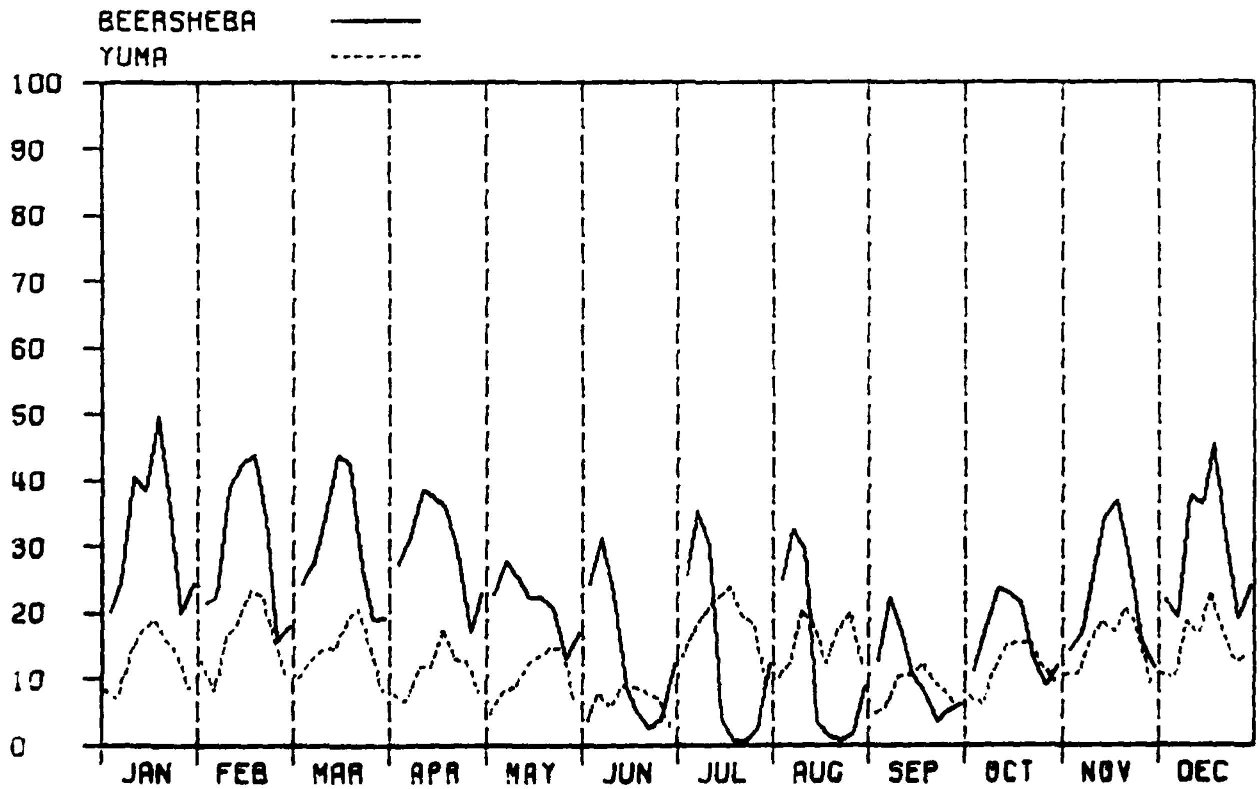
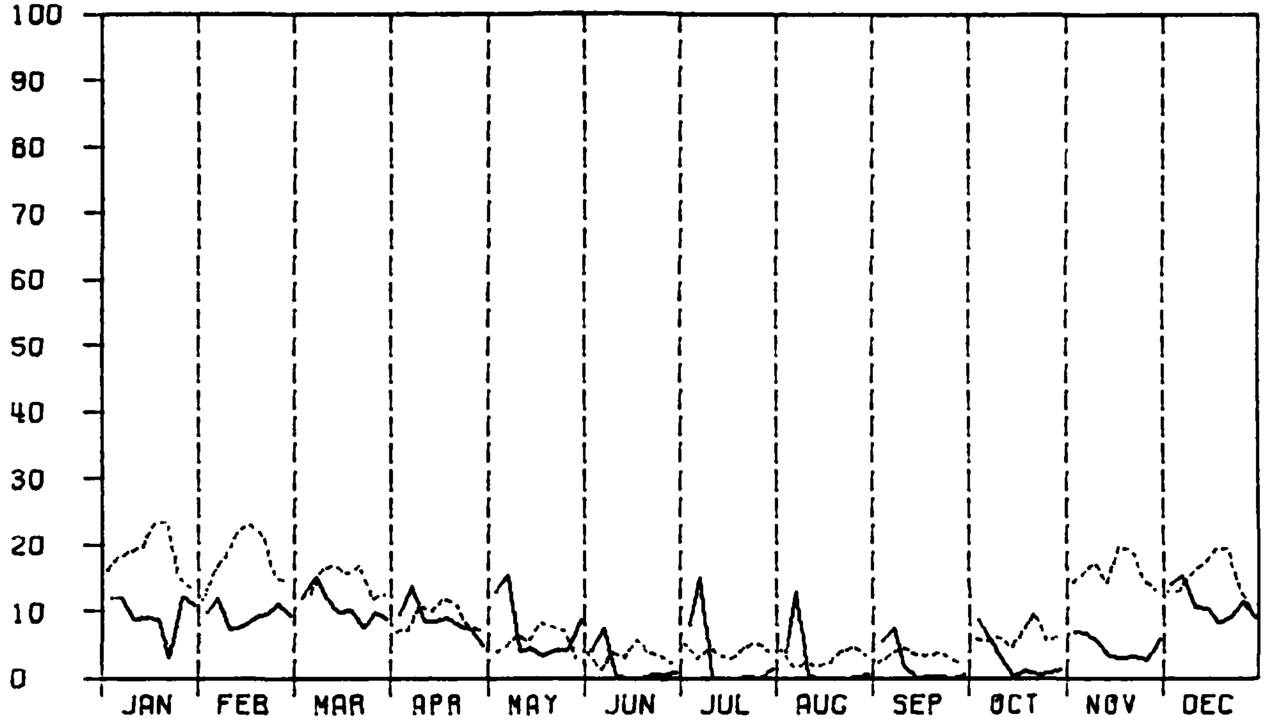



Fig. 17. (Cont'd) TOTAL SKY COVER
CLASS = OVERCAST
FREQUENCY (IN PER CENT). BY 3-HOURLY PERIOD AND BY MONTH

BEERSHEBA ———
DAGGETT --------




BEERSHEBA ———
EL PASO --------

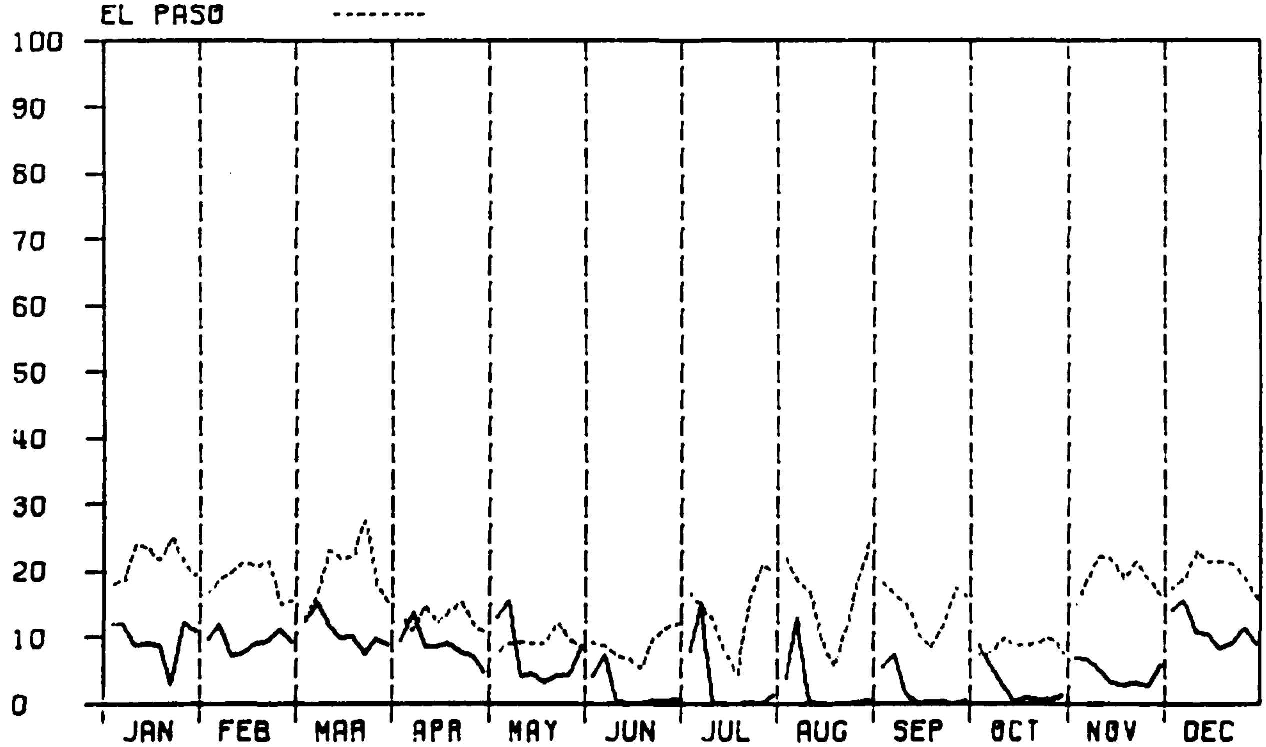
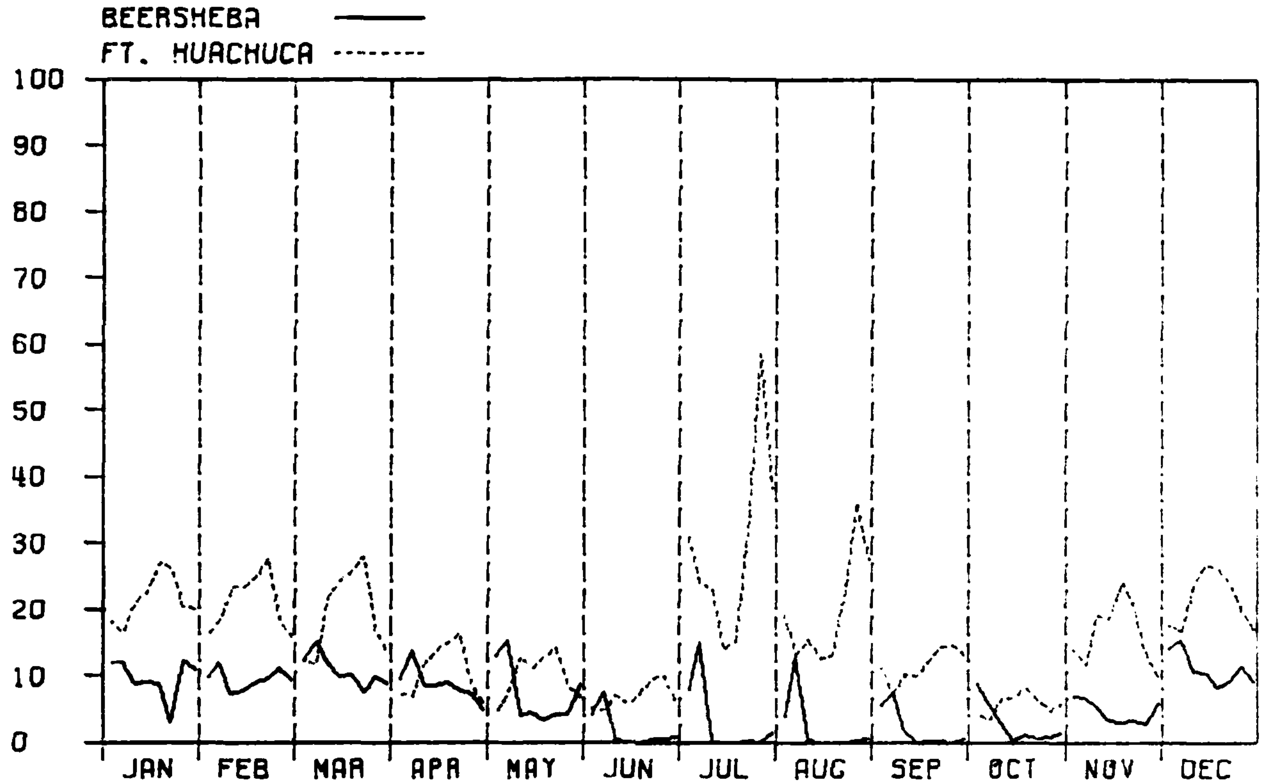


Fig. 17. (Cont'd) TOTAL SKY COVER
CLASS = OVERCAST
FREQUENCY (IN PER CENT). BY 3-HOURLY PERIOD AND BY MONTH



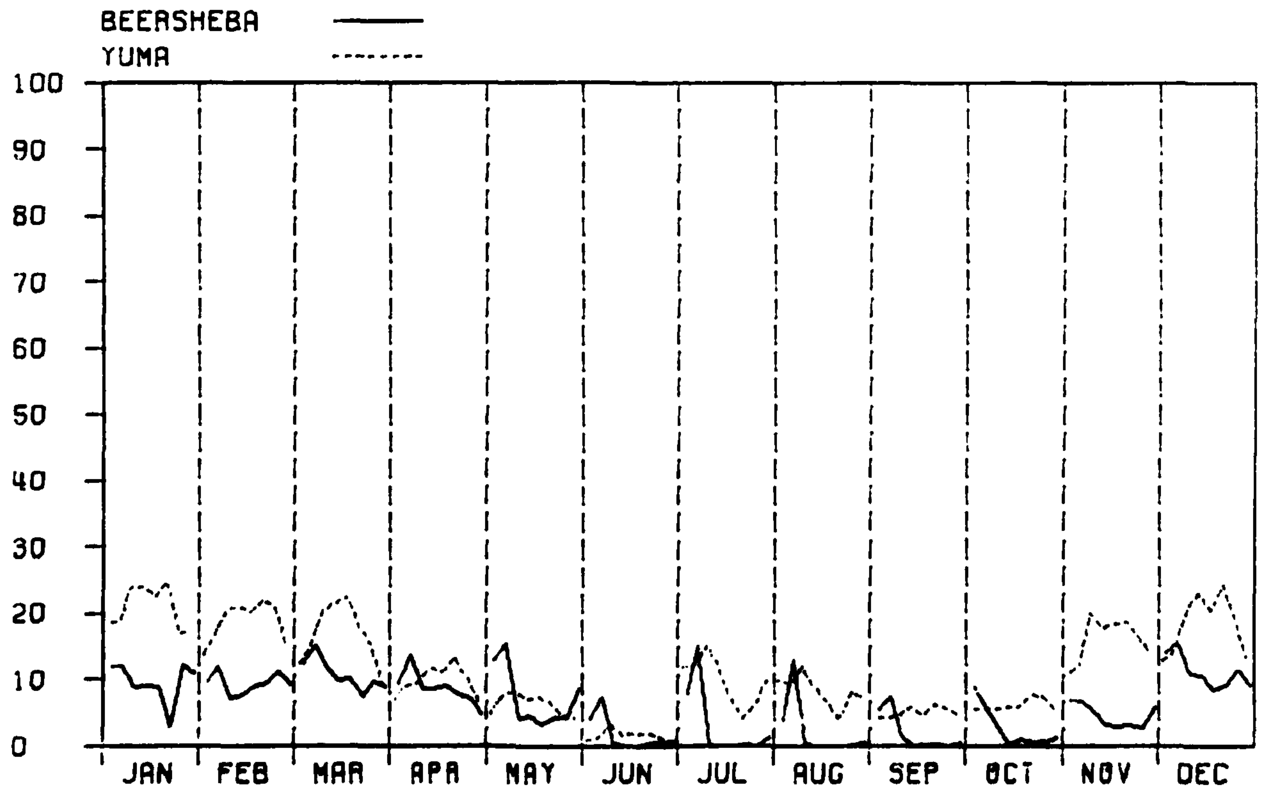



Fig. 18. TOTAL SKY COVER
CLASS = CLEAR
FREQUENCY (IN PER CENT), BY MONTH

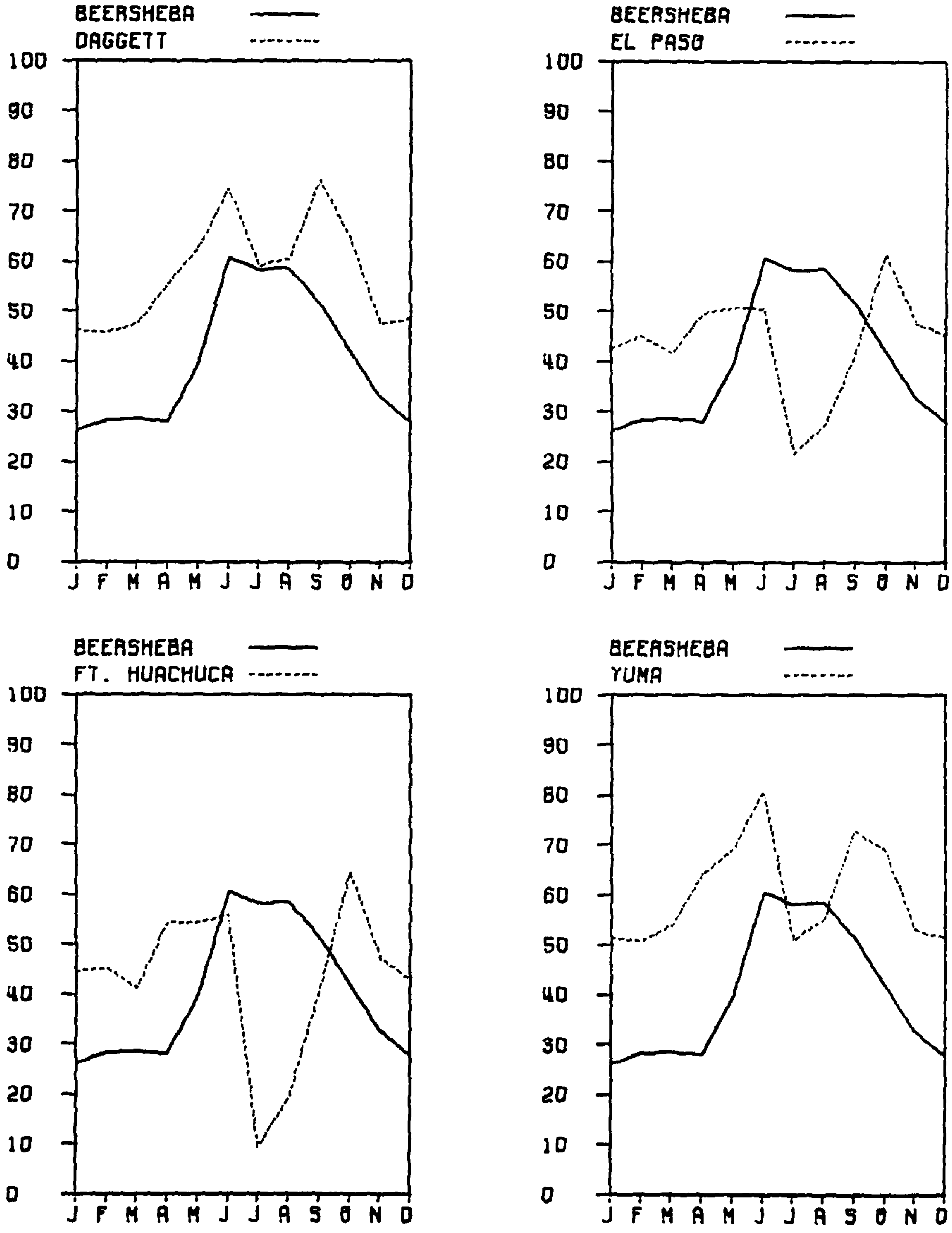


Fig. 18. (Cont'd) TOTAL SKY COVER
CLASS = SCATTERED
FREQUENCY (IN PER CENT). BY MONTH

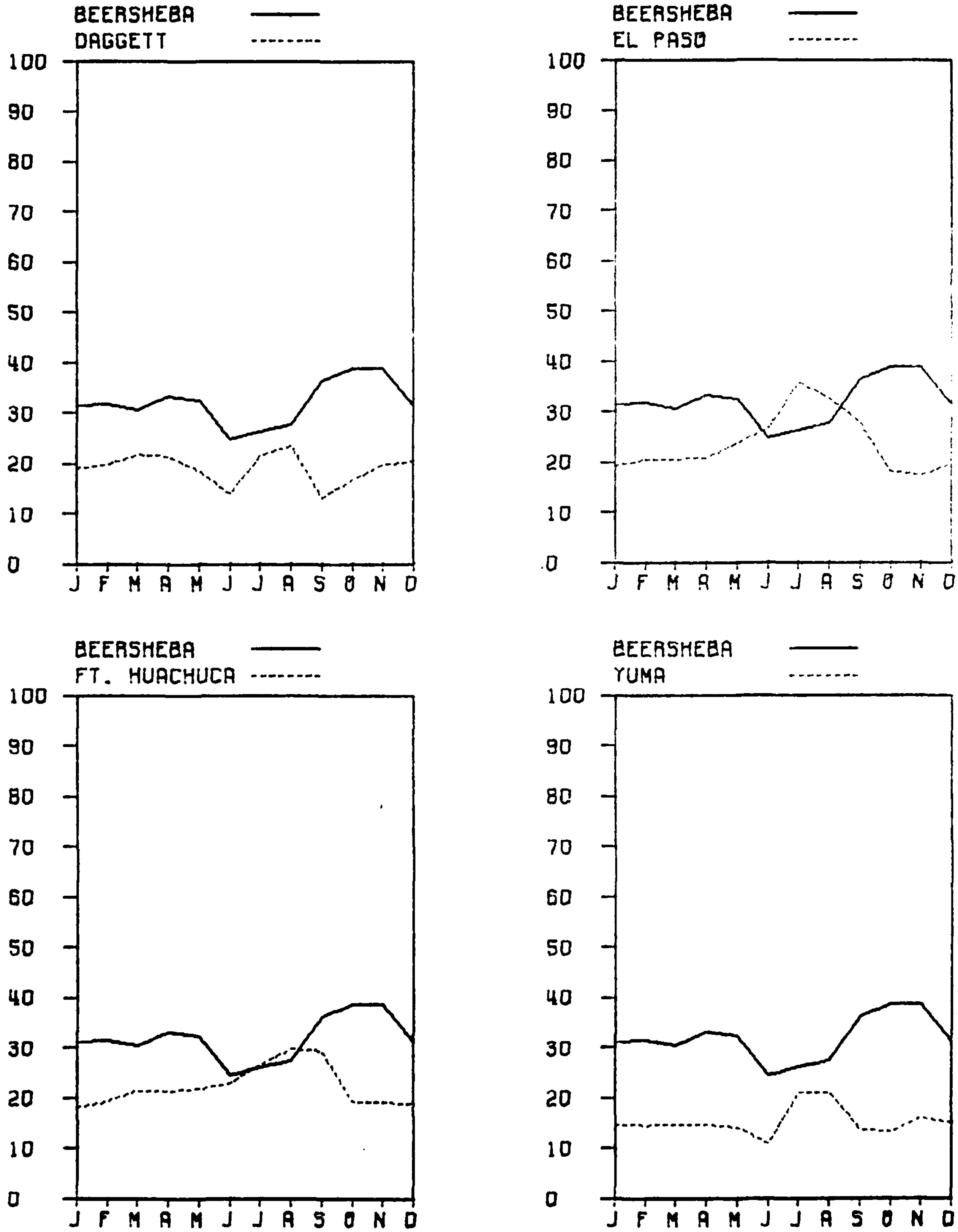


Fig. 18. (Cont'd) TOTAL SKY COVER
CLASS = BROKEN
FREQUENCY (IN PER CENT), BY MONTH

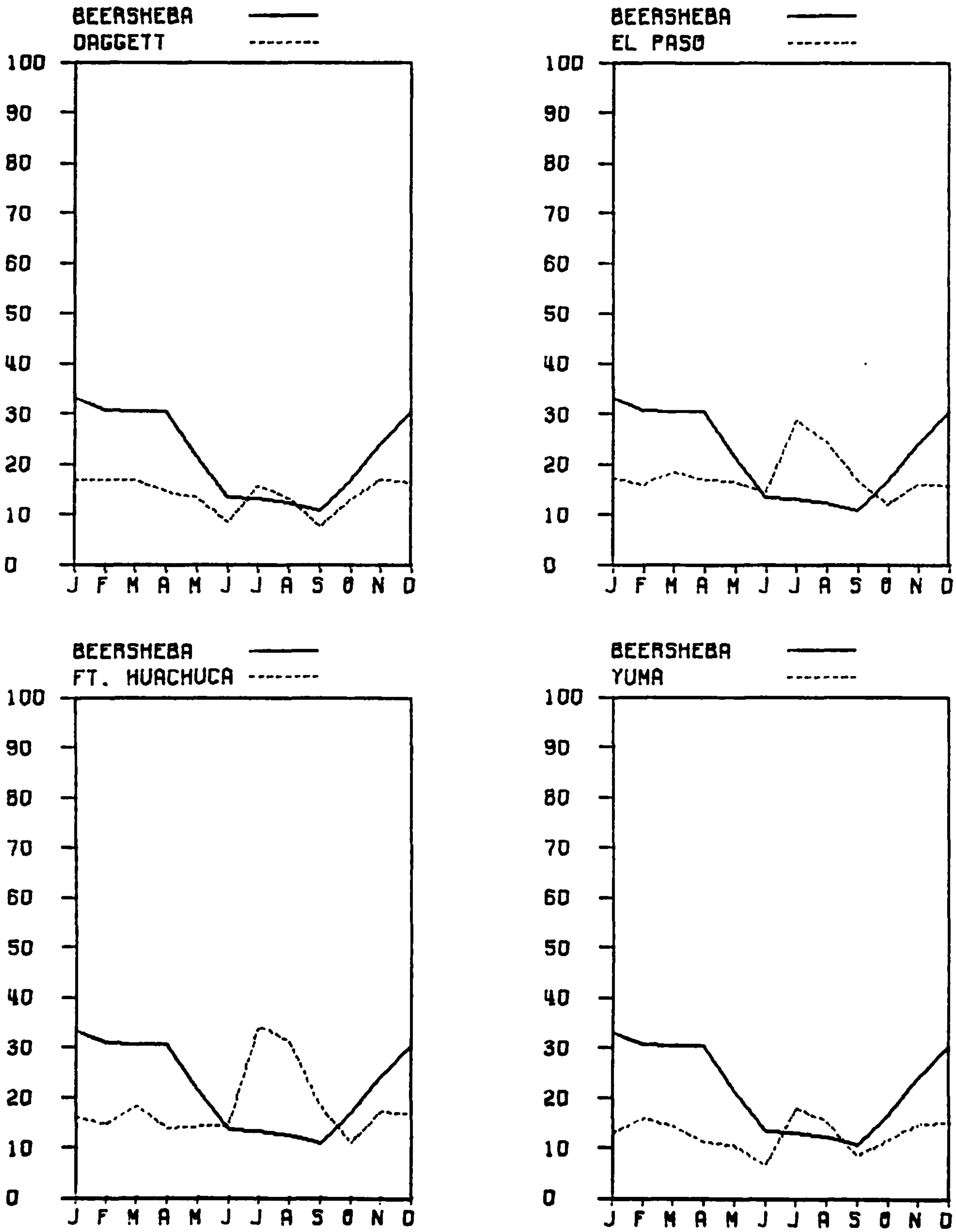
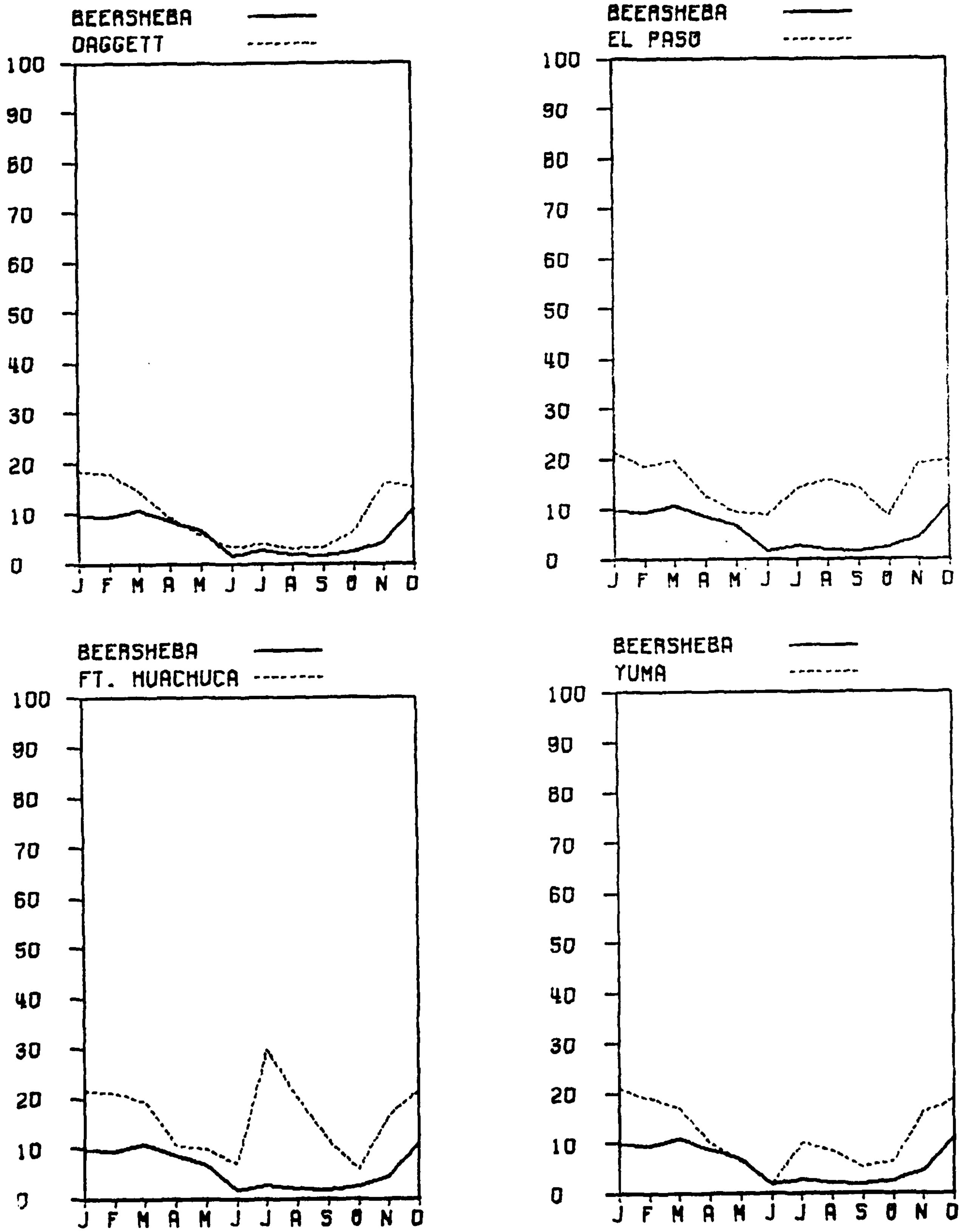


Fig. 18. (Cont'd) TOTAL SKY COVER
CLASS = OVERCAST
FREQUENCY (IN PER CENT). BY MONTH



H. Present Weather

1. Matching Codes

The present weather code in a weather report tells what is happening at the station at the time of observation. The Beersheba data are given in the Synoptic Code whereas the U.S. data are given in the Airways Code. The Synoptic Code contains 100 types of weather coded from 00 to 99 from which one type is selected at each 3-hourly observation. The coded values 00-49 indicate no precipitation at the station at the time of observation; the values 50-99 indicate that some form of precipitation has occurred. The code is divided into groups of similar types of weather. For example, numbers 30-39 deal with duststorms, sandstorms, drifting or blowing snow and numbers 60-69 deal with different types of rain (e.g., freezing, slight; freezing, moderate or heavy).

In contrast, the Airways Code has four categories of weather with each containing groupings of similar types of weather. The four categories are the occurrence of a thunderstorm, tornado or squall, occurrence of liquid precipitation, occurrence of freezing precipitation, and occurrence of an obstruction to visibility. Whereas in the Synoptic Code only one coded value or weather type can be reported at the time of observation, in the Airways Code more than one coded value or weather type can be reported. Usually,

when weather is occurring, only one of the four categories is non-zero (zero meaning none).

The problem is how to blend the two codes in order to achieve a valid comparison scheme for present weather at the U.S. stations with present weather at Beersheba. The first part of the solution was to create a third code with each category incorporating appropriate coded values in the Synoptic and Airways Codes. The new code is concerned only with present weather that would likely impair visibility. Table 7 shows the new code in terms of the other codes. The definitions attached to the Synoptic and Airways Codes can be found in weather observing manuals or obtained from the National Weather Service.

The second part of the solution was to rank the four categories in the Airways Code in the order of their importance in obstructing visibility. The ranking used was thunderstorm, tornado or squall, obstruction to visibility, liquid precipitation and freezing precipitation. If a thunderstorm was occurring at the time of observation the other three categories were ignored.

If there was a zero in the thunderstorm, tornado or squall category then the obstruction to visibility category was queried and treated in the same manner as the previous category. In this way there was only one coded value per observation time for both the Synoptic and Airways Codes.

Table 7. The new present weather code in terms of the Synoptic and Airways Codes.

| New Code Number | Definition* | Synoptic Code Number | Airways Code Field (Number) |
|---|---|---|---|
| 00 | None | 00-03 | 129-136(0) |
| 11 | Thunderstorm | 17, 95, 96, 98 | 129(1) |
| 12 | Thunderstorm+ | 97, 99 | 129(2) |
| 21 | Smoke | 04 | 136(1) |
| 22 | Haze | 05 | 136(2,3) |
| 23 | Dust- | 06-09 | 136(4) |
| 24 | Dust | 30-32 | 135(4) |
| 25 | Dust+ | 33-35 | 135(5) |
| 26 | Fog | 10-12, 40-49 | 135(1-3) |
| 27 | Blowing Snow | 36-39 | 136(5) |
| 31 | Drizzle- | 50, 51, 56 | 131(4,7) |
| 32 | Drizzle | 52, 53, 57 | 131(5,8) |
| 33 | Drizzle+ | 54, 55 | 131(6,9) |
| 34 | Rain- | 58, 60, 61, 66, 68, 80, 83 | 130(1,4,7), 131(1) |
| 35 | Rain | 59, 62, 63, 67, 69, 81, 84 | 130(2,5,8), 131(2) |
| 36 | Rain+ | 64, 65, 82 | 130(3,6,9), 131(3) |
| 41 | Snow- | 70, 71, 85, 87 | 132(1,4,7), 133(1,4,7) |
| 42 | Snow | 72, 73, 86, 88 | 132(2,5,8), 133(2,5,8) |
| 43 | Snow+ | 74, 75 | 132(3,6,9), 133(3,6,9) |
| 44 | Hail | 79, 89, 90 | 134(1-9) |
| 88 | Other | Other than above | Other than above |
| 99 | Invalid or Missing | - | - |

* - light intensity; + heavy intensity

2. Computation of Frequency of Occurrence in Percent

The calculation of frequency of occurrence was done somewhat differently for present weather than that described in Section IV.C. The 3-hourly observations were placed into daytime and nighttime classes. The daytime class includes observation times (in local mean solar time) 0700 or 0800, 1000 or 1100, 1300 or 1400, and 1600 or 1700; the nighttime class includes 1900 or 2000, 2200 or 2300, 0100 or 0200, and 0400 or 0500. The observation times in each class did not change with season.

The formula for the frequency of occurrence of weather type X in class c (either daytime or nighttime) is

$$fX_{cm} = \frac{1}{(H/2)YD} \sum_{y=1}^{Y} \sum_{d=1}^{D} \sum_{h=1}^{H/2} X_{cymdh}$$

where the notation corresponds to that in Section IV.C.

The results of the calculations showed that a number of the weather types didn't occur at all or occurred very seldom. Therefore, it was decided to plot only those weather types that occurred, on the average, 1% or more of the day or night observation times for any month. This is equivalent to 1.2 times per 30 day month in each class ($0.01 \times 4$ obs $\text{day}^{-1} \times$ 30 days). If any station satisfied the criterion for a given weather type, it was plotted for all stations. Of

the 21 possible weather types 13 were eliminated using this criterion. The remaining 8 are discussed in the next section.

3. Comparative Analysis

Fig. 19a shows the frequency of occurrence in percent of no weather during the daytime and nighttime and by month. Clearly the occurrence of no weather is more frequent at any U.S. station than at Beersheba. At Yuma, only about 2% of the observation times show the occurrence of some type of weather. The percentages are not much greater at Daggett and El Paso. Ft. Huachuca shows a sharp minimum in the occurrence of no weather during July and August. As will be seen later this is due to, not unexpectedly, thunderstorm occurrence. The frequency of occurrence of no weather is about 20% less at Beersheba than at the other stations. Except for Beersheba the day and night curves are not much different.

As seen in Fig. 19b fog occurs much less often at the U.S. stations than at Beersheba. The few there are occur mainly in the winter months while the maximum at Beersheba occurs in the summer months. El Paso has the highest occurrence of fog among the U.S. stations with an average of 5 in December. This is in contrast to Beersheba where about 17 fog conditions are reported during the nighttime in July and only 1 or 2 during the daytime. Apparently fog contributes significantly to the high frequency of poor visibility (<10 km) during nighttime (see Fig. 15) and to nocturnal overcast skies, especially at 0500 (see Fig. 17).

Haze is also far more prevalent at Beersheba than at the other stations. Fig. 19c shows that Beersheba has an average of about 22 haze conditions reported in the daytime observations in April while Daggett, the U.S. station with the highest occurrence, shows an average of about 6 during November. The frequency of daytime haze at Beersheba is about the same as the frequency of nighttime haze during the winter months, but less frequent during the remainder of the year.

Fig. 19d shows the frequency of occurrence for light dust and 19e the same for moderate dust. By comparison with fog and haze, dust is not a frequent obscurant at Beersheba. In both figures dust occurs more frequently during the daylight hours than nighttime hours, presumably caused by higher wind speeds.

In contrast to Beersheba moderate dust is more frequent than light dust at the U.S. stations. El Paso shows a pronounced peak in the occurrence of moderate dust during the daytime in April.

The frequency of light rain is plotted in Fig. 19f. Both the day and night curves for Beersheba approximate the curve of annual rainfall. During the winter season (November-April) all U.S. stations except Ft. Huachuca show frequencies lower than Beersheba, day or night. During the summer all U.S. stations receive more rainfall than Beersheba

(see Table 1) so, as Fig. 19f shows, they have higher frequencies during this period.

Among the U.S. stations Daggett and Yuma show fairly uniform annual distributions of light rain. El Paso and Ft. Huachuca both have noticeable winter and summer peaks during the nighttime hours.

As is readily evident in Fig. 19g, thunderstorms seldom occur in Beersheba and Yuma. At the other stations the thunderstorms occur mainly during the warm season, as expected. The frequencies of occurrence at Ft. Huachuca suggest that during July about one-half the days have thunderstorms. As discussed in the climate summary for Ft. Huachuca, these are due to convection combined with orographic lifting.

The frequencies for light snow, shown in Fig. 19h, are presented because El Paso alone meets the criterion for plotting. Snow has occurred at all stations, although for Daggett, Yuma and Beersheba there may be a number of years between occurrences. For all stations snow is neither an important climate factor nor an important obscurant.

Fig. 19a. CURRENT WEATHER
CLASS = NONE
FREQUENCY (IN PER CENT), BY NIGHT OR DAY, AND BY MONTH

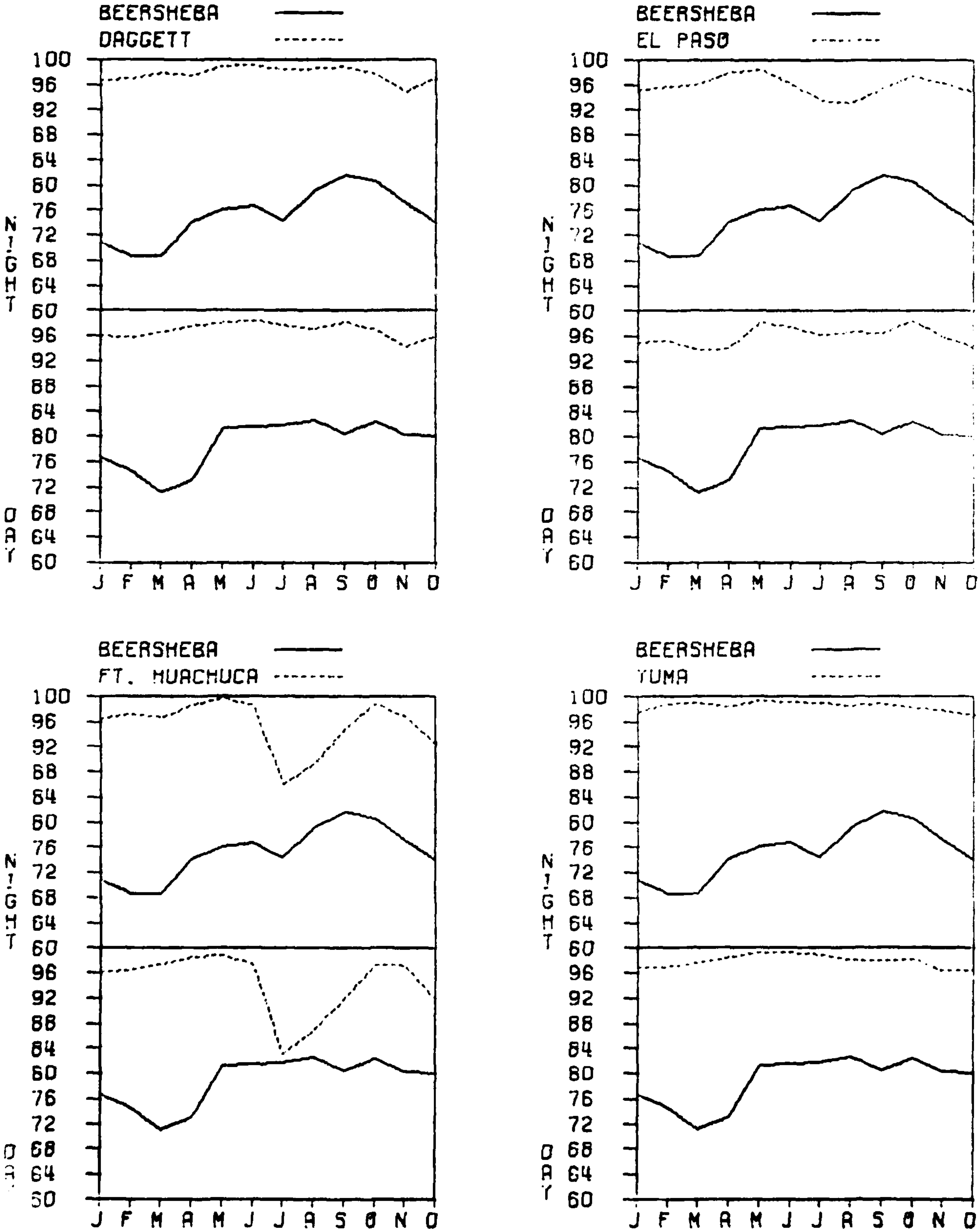


Fig. 19b. CURRENT WEATHER
CLASS = FOG
FREQUENCY (IN PER CENT), BY NIGHT OR DAY, AND BY MONTH

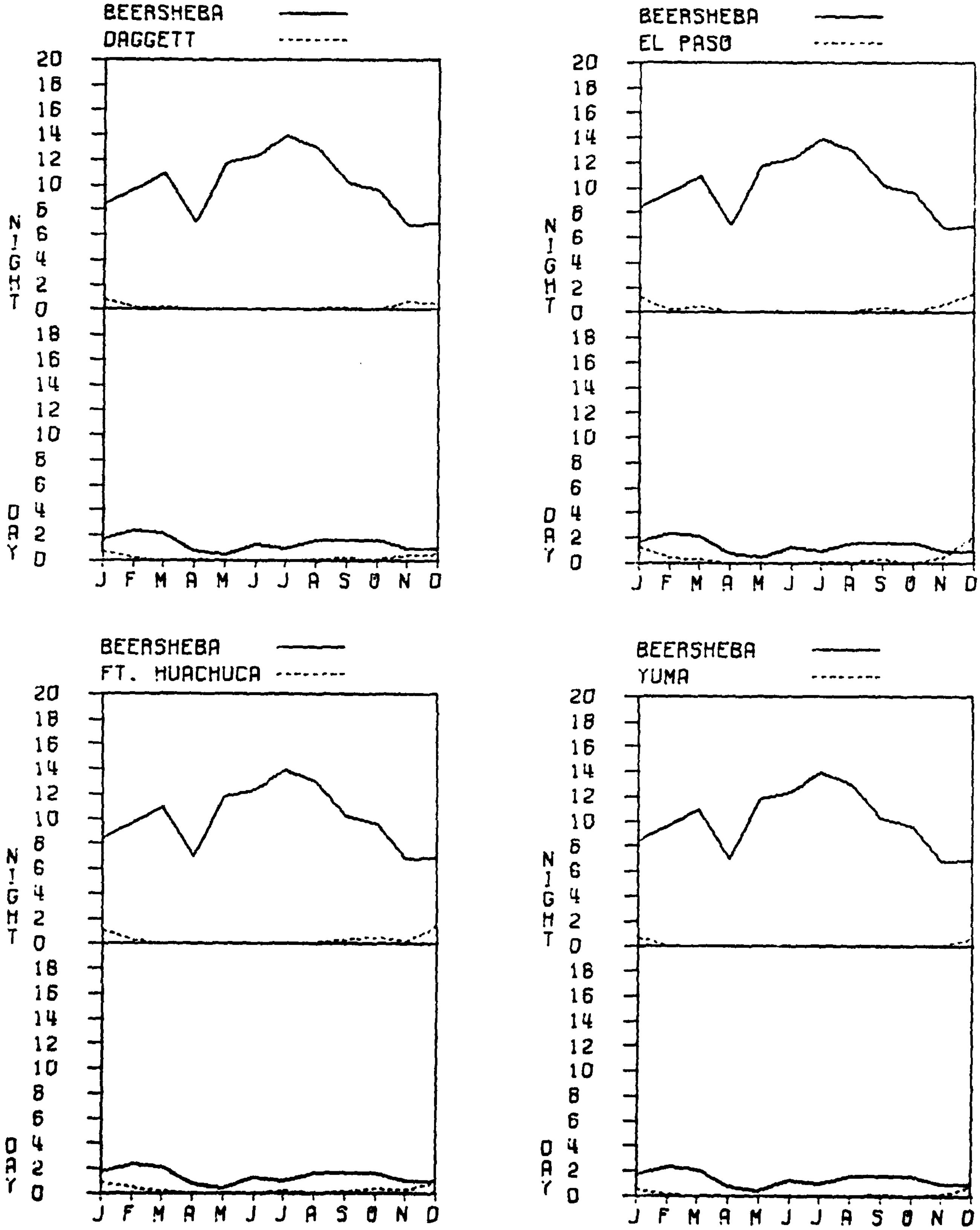


Fig. 19c. CURRENT WEATHER
CLASS = HAZE
FREQUENCY (IN PER CENT), BY NIGHT OR DAY, AND BY MONTH

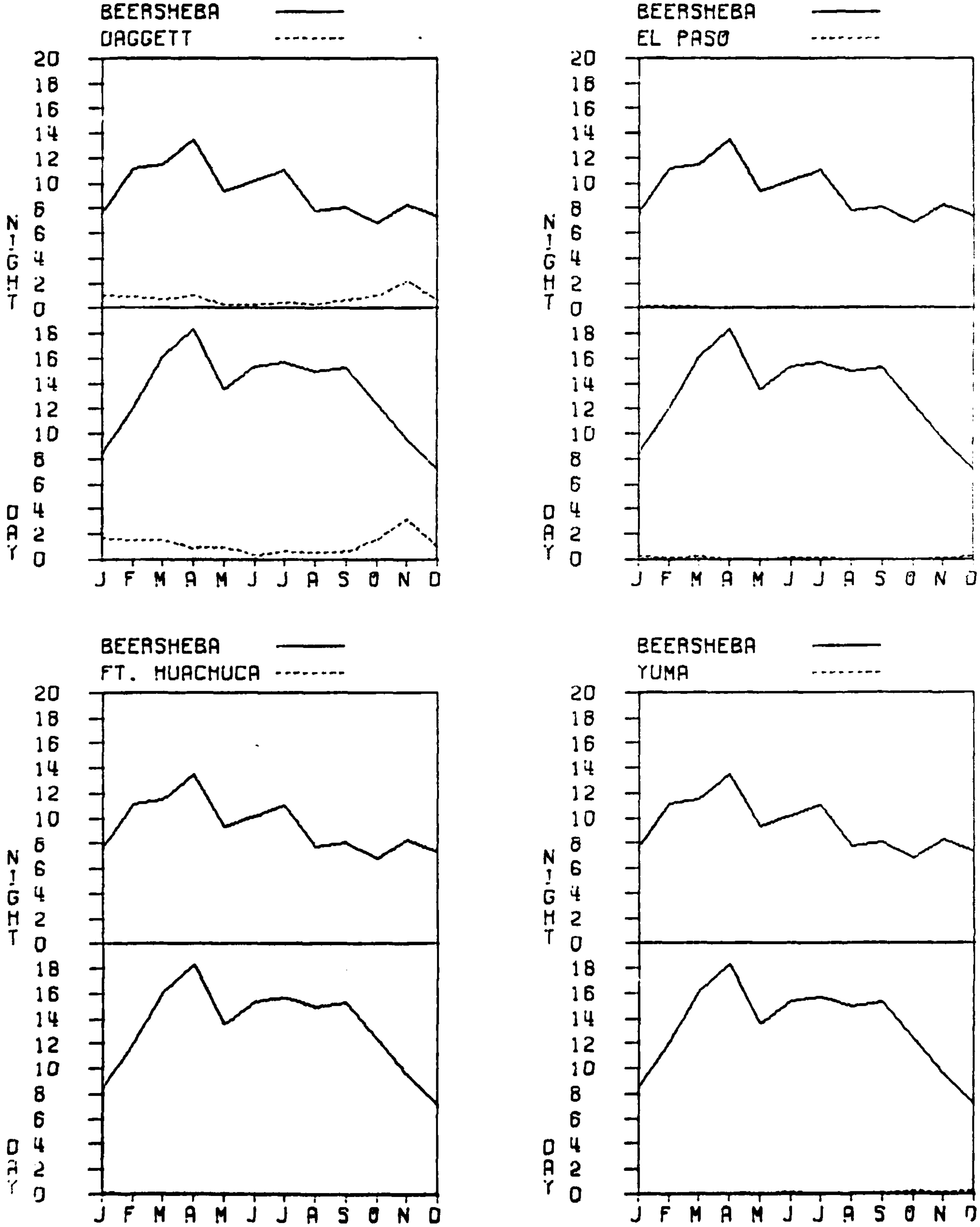


Fig. 19d. CURRENT WEATHER
CLASS = DUST-
FREQUENCY (IN PER CENT), BY NIGHT OR DAY, AND BY MONTH

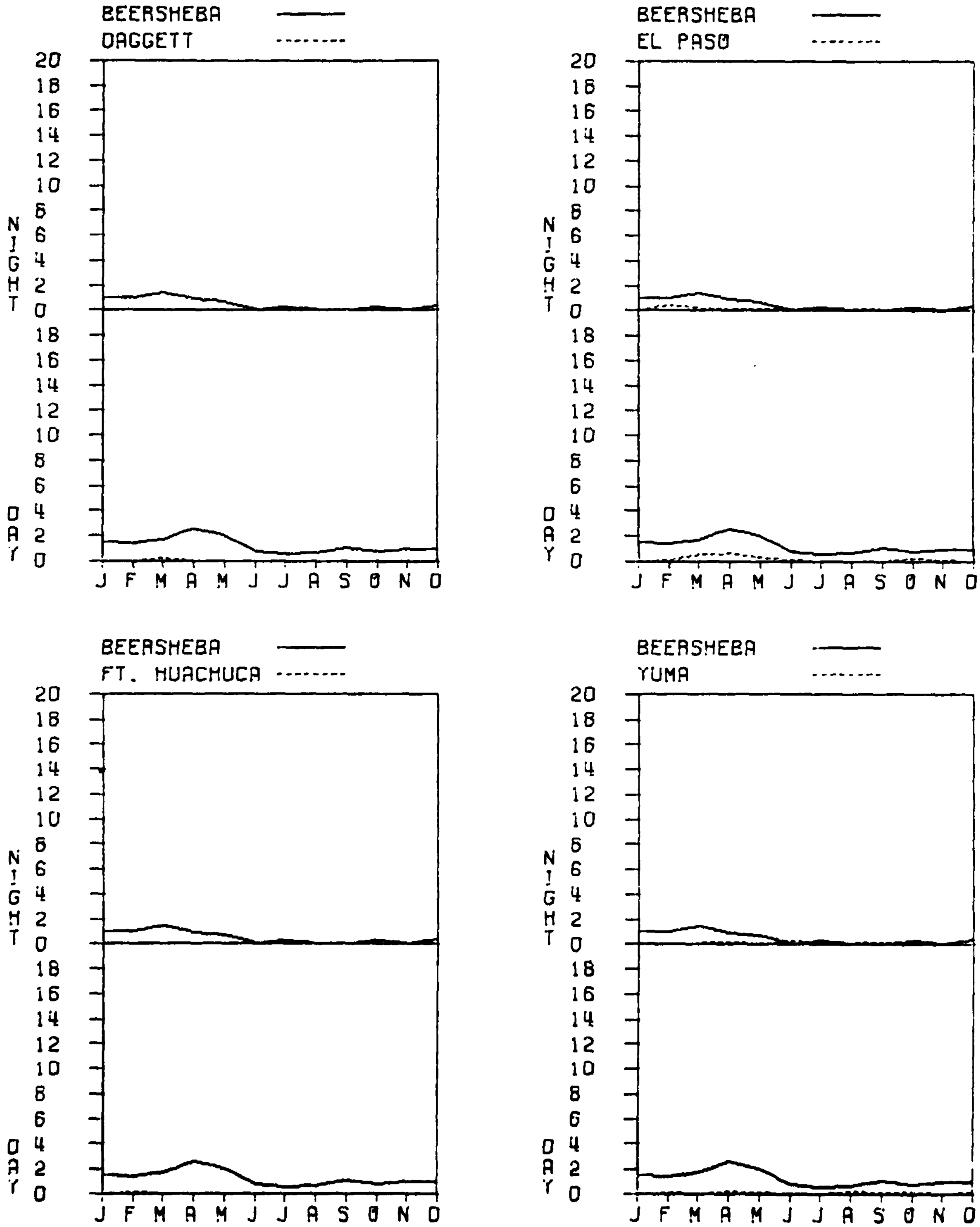
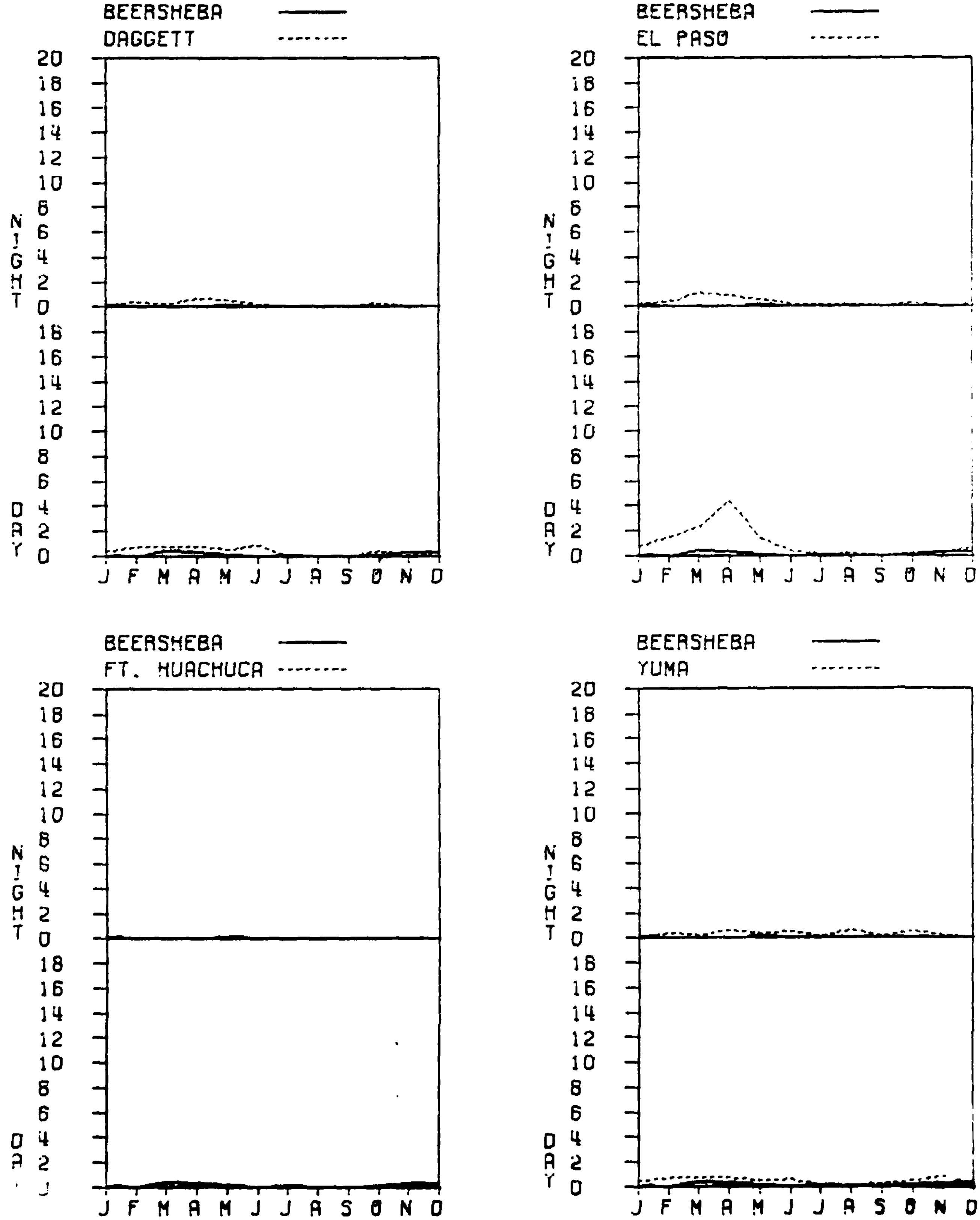


Fig. 19e. CURRENT WEATHER
CLASS = DUST
FREQUENCY (IN PER CENT), BY NIGHT OR DAY, AND BY MONTH



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COMPARISON OF THE CLIMATES OF SELECTED LOCATIONS IN THE UNITED --ETC(U)

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UNCLASSIFIED ERADCOM/ASL-CR-81-0100-2 NL

2 of 3

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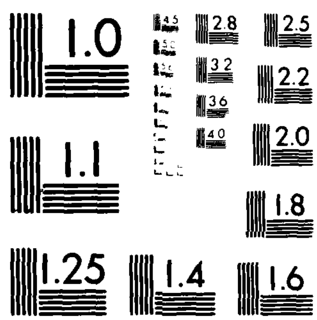



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963 A

Fig. 19f. CURRENT WEATHER
CLASS = RAIN-
FREQUENCY (IN PER CENT). BY NIGHT OR DAY. AND BY MONTH

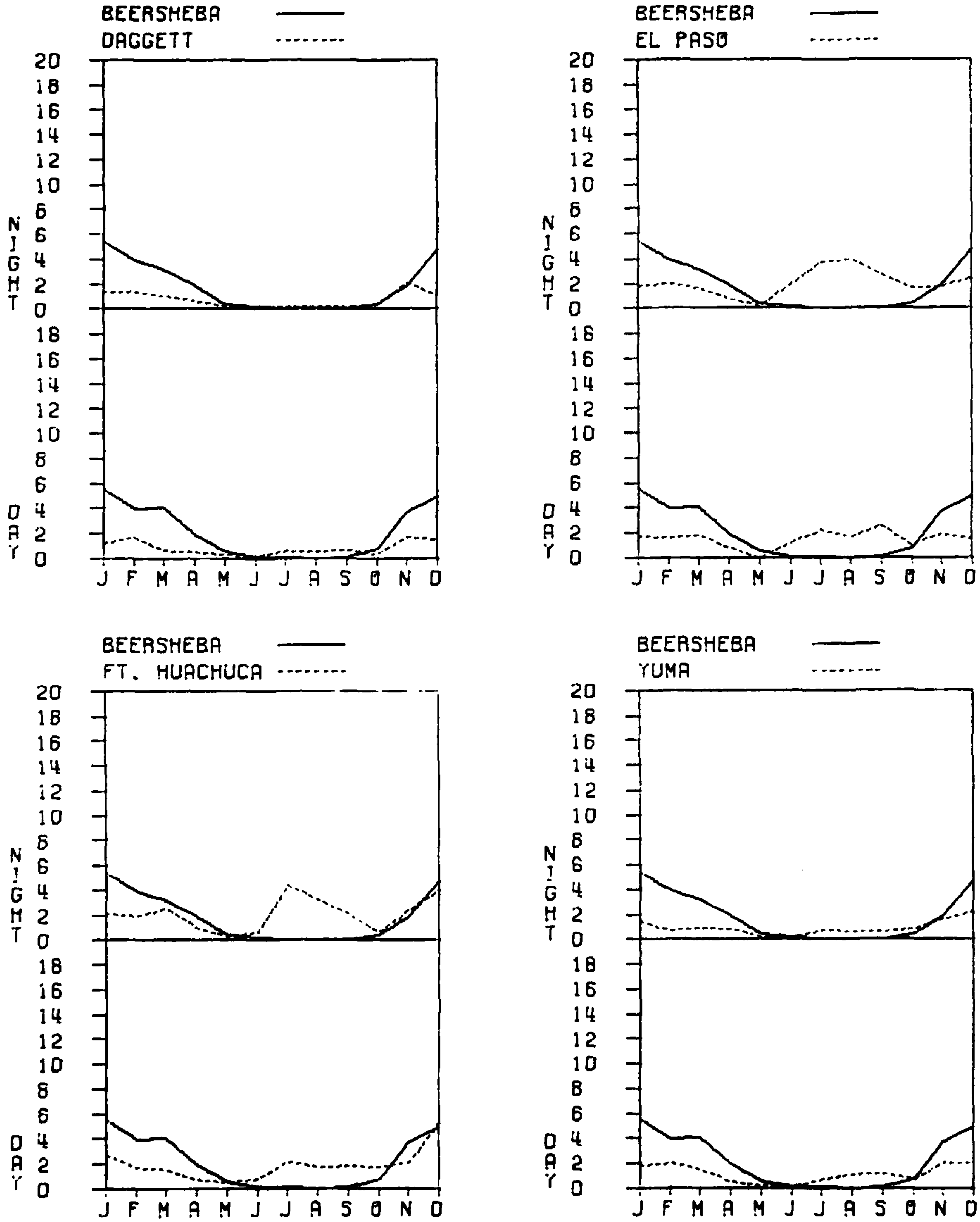


Fig. 19g. CURRENT WEATHER
CLASS = T. STORM
FREQUENCY (IN PER CENT), BY NIGHT OR DAY, AND BY MONTH

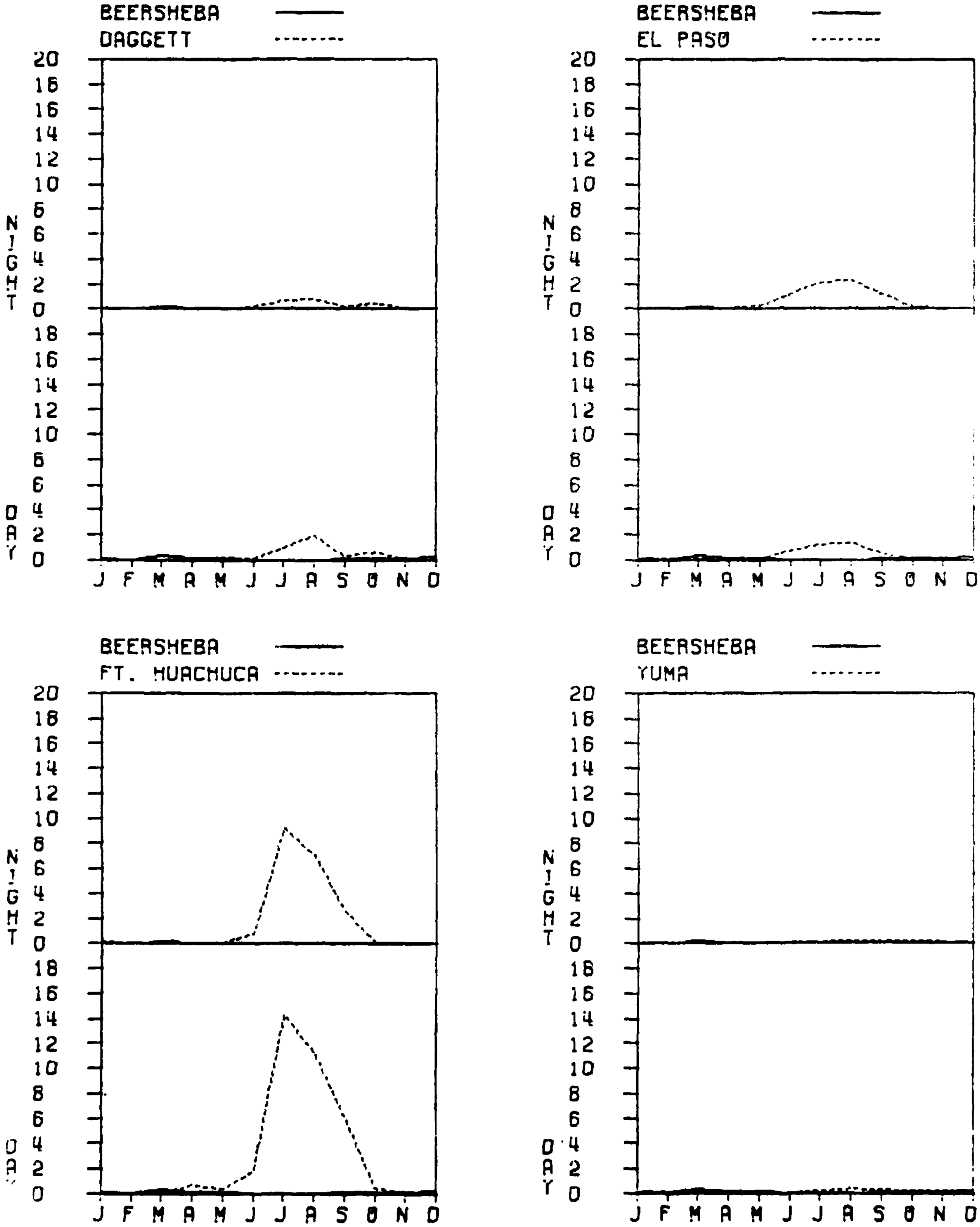
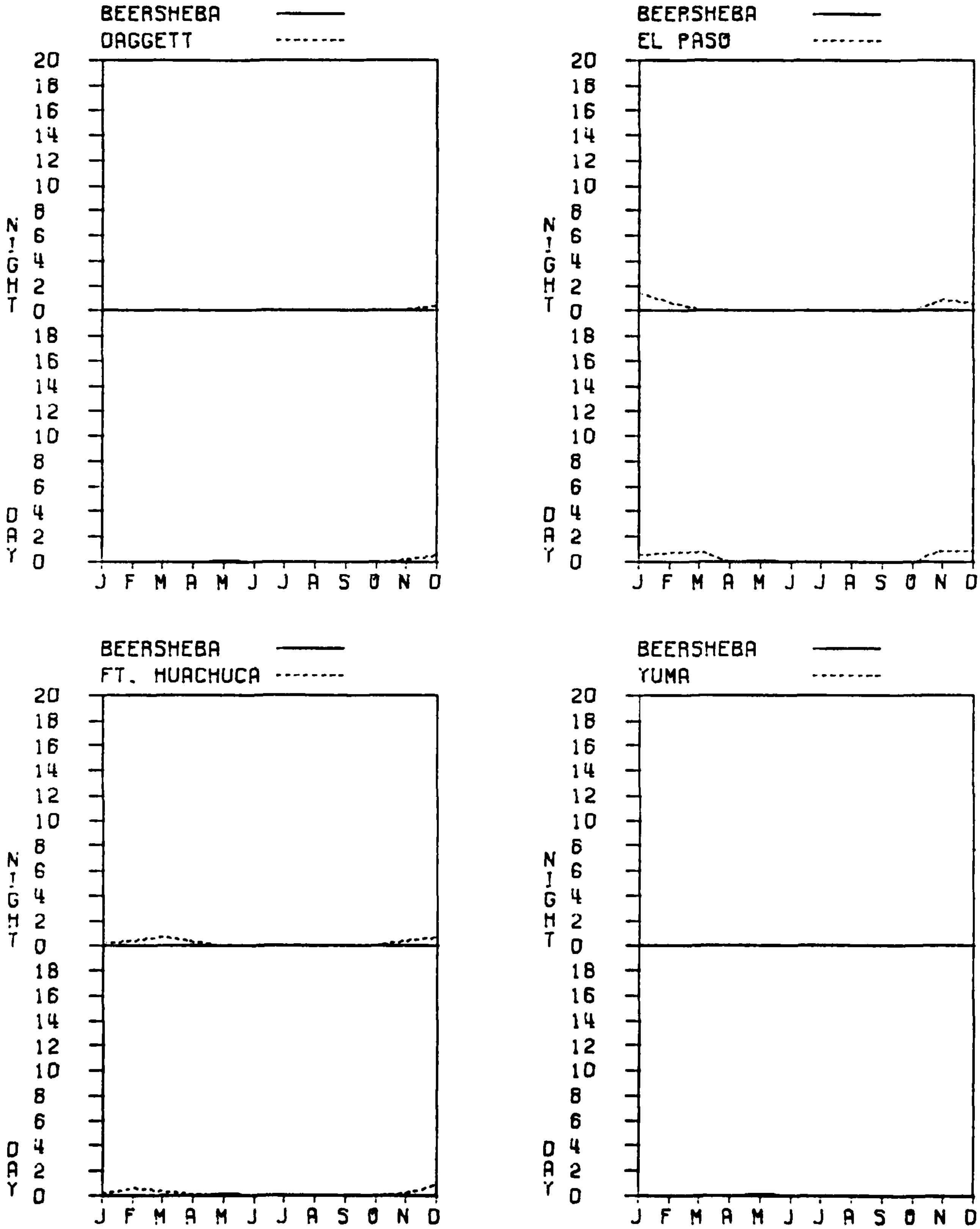


Fig. 19h. CURRENT WEATHER
CLASS = SNOW-
FREQUENCY (IN PER CENT). BY NIGHT OR DAY. AND BY MONTH



## VI. SUMMARY AND CONCLUSIONS

Daily and annual variations of 13 meteorological variables have been computed for four U.S. stations and Beersheba, Israel. Eight of the variables are considered to be of primary interest for this study and are discussed in section V. They are dry bulb temperature, dew point, relative humidity, wind speed, stability, visibility, total sky cover, and present weather. The five other variables, absolute humidity, wind direction, lowest cloud layer, ceiling height and sea-level pressure are discussed in Appendix A. The four U.S. stations are Daggett, California, El Paso, Texas, Ft. Huachuca, Arizona, and Yuma, Arizona. The purpose of the study was to compare the climatology of the U.S. stations with that of Beersheba in the hope that one or more would show a strong resemblance to Beersheba. Plots were made so that one can compare the daily cycle and monthly means of each variable for each U.S. station directly with Beersheba. Ten years of data were analyzed for the U.S. stations and 12 years for Beersheba, although because of missing data, the effective length is also about 10 years.

The results show that the annual temperature range for Beersheba is less than any U.S. station although the annual mean is about the same as at Ft. Huachuca and El Paso. The smaller annual range in temperature is to some extent due to the higher moisture content of the air at Beersheba than at the U.S. stations. The mean annual relative humidity is

more than 60% at Beersheba while at the U.S. stations it varies from 30 to 40%. The daily range in relative humidity is also large compared to U.S. stations but the annual range is small.

The daily range of wind speed at Beersheba is the largest among the five stations while the annual range of monthly means is the smallest. The mean annual wind speed at Beersheba is not much less than that at El Paso, Ft. Huachuca and Yuma. Similarly, the Beersheba stability has a wider daily range and smaller annual range than the other stations. The average annual stability is about the same for all stations.

Visibility is, in general, significantly poorer at Beersheba than any U.S. station. Fog, haze, and light dust, comparatively common phenomena at Beersheba, account for most of the obscuration. The skies are generally cloudier during the cool season (November-April) at Beersheba than at the other stations although the occurrence of overcast skies is least at Beersheba.

One feature of the comparison analysis stands out; it is the large daily range of all variables except dry bulb temperature (and present weather) at Beersheba, a feature generally poorly matched at the U.S. stations.

Of the four U.S. stations studied, Ft. Huachuca and El Paso provide the better models of Beersheba for the variables analyzed. However, the selection of the station (or the selection of any at all) really depends on which are the crucial variables for the intended field operations.

It is unlikely that any station in the U.S. (not just the ones studied) will provide a good model of Beersheba climate. The proximity of a large warm body of water to the west, the high moisture content of the air, the large daily range in many meteorological variables, and the relatively frequent fog, haze, and dust are features not common to any part of the U.S. It may well be that the U.S. stations (especially Yuma, El Paso, and Daggett) better match the central and southern Negev which is hotter and drier than the northern Negev and is representative of the vast desert regions to the east and west of the Negev.

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# APPENDIX A

## COMPARISON OF THE MEANS AND FREQUENCIES OF THE SECONDARY VARIABLES

### A. Introduction

In this Appendix the means or frequencies of lowest cloud height, ceiling height, wind direction, absolute humidity and sea-level pressure are presented and discussed. They are considered to be secondary variables because they influence obscuration in the lower planetary boundary layer in a subsidiary way or because their principal characteristics have been already analyzed through discussion of other primary variables. Nevertheless, they add to the total picture of comparing the climates at the U.S. stations with the climate of Beersheba.

B. Lowest Cloud Height

Lowest cloud height means the height above ground of the base of the lowest cloud layer or obscuring phenomena seen. The Synoptic Code has 9 height layers, the lowest being 0-49 m and the highest 2500 m or more, or no clouds. The Airways Code identifies the lowest cloud height in hundreds of feet from the surface to 80,000 ft. and uses a special code for no clouds seen. In order to provide a common classification, the layers in the Synoptic Code were combined to yield five layers: 0-49 m, 50-199 m, 200-999 m, 1000-2500 m and >2500 m. Each Airways coded height was placed into one of the five categories where the category >2500 m includes no clouds present.

Fig. 20 shows the 3-hourly frequency of occurrence of lowest cloud height by month. Before proceeding it should be pointed out that there were no lowest cloud heights available for Daggett at any time of observation and for Yuma at 2200 and 0100. Both features become obvious when examining the plots.

The frequency of lowest cloud height in the 0-49 m layer is highest at Beersheba which shows non-zero values year round. These low heights are, no doubt, due mostly to the year round occurrence of fog as observed in Fig. 19b. The few occurrences of lowest cloud heights in the 0-49 m layer at El Paso and Ft. Huachuca during the winter are also coincident with their maximum frequencies of fog (see Fig. 19b).

The frequency of occurrence of lowest cloud heights in the 50 to 199 m layer is, for all stations, small compared to the frequency of occurrence in the other layers. In other words, except for fog, cloud bases tend not to occur below 200 m.

In the 200-999 m range the frequencies of each of the three U.S. stations are often lower than Beersheba by a factor of 2 or more. The high frequency during the early morning and low frequency during the late morning and afternoon at Beersheba during the warm season suggests low stratus coming from the Mediterranean Sea in the early morning, then evaporating a few hours later.

In the 1000-2499 m range Beersheba shows a daily pattern of frequencies that is similar in phase and not much different in amplitude from one month to the next. The highest frequency occurs during the early afternoon, then drops sharply to a minimum in the evening. The U.S. stations, notably El Paso and Ft. Huachuca, show a strong increase in the mean and amplitude of the daily oscillation from winter to summer. This can be attributed to the seasonal increase in the amount of surface heating on the slopes of the adjacent mountains coupled with orographic lifting. At Ft. Huachuca at 1700 hr in July and August there is a 99% chance of finding the lowest cloud height in this layer. The comparable figure for El Paso is 95%, except that the maximum occurs at 1400 hr.

The plots for lowest cloud height $\geq$2500 m or no clouds show that for the three U.S. stations the maximum frequency

invariably occurs in the evening hours and the minimum in the afternoon hours. During the cool season (November-April) Beersheba has a similar pattern but during May-September the maximum frequency is in the late afternoon or early evening and the minimum in the early morning. The early morning minimum agrees with the high occurrence of low stratus mentioned above and the occurrence of fog.

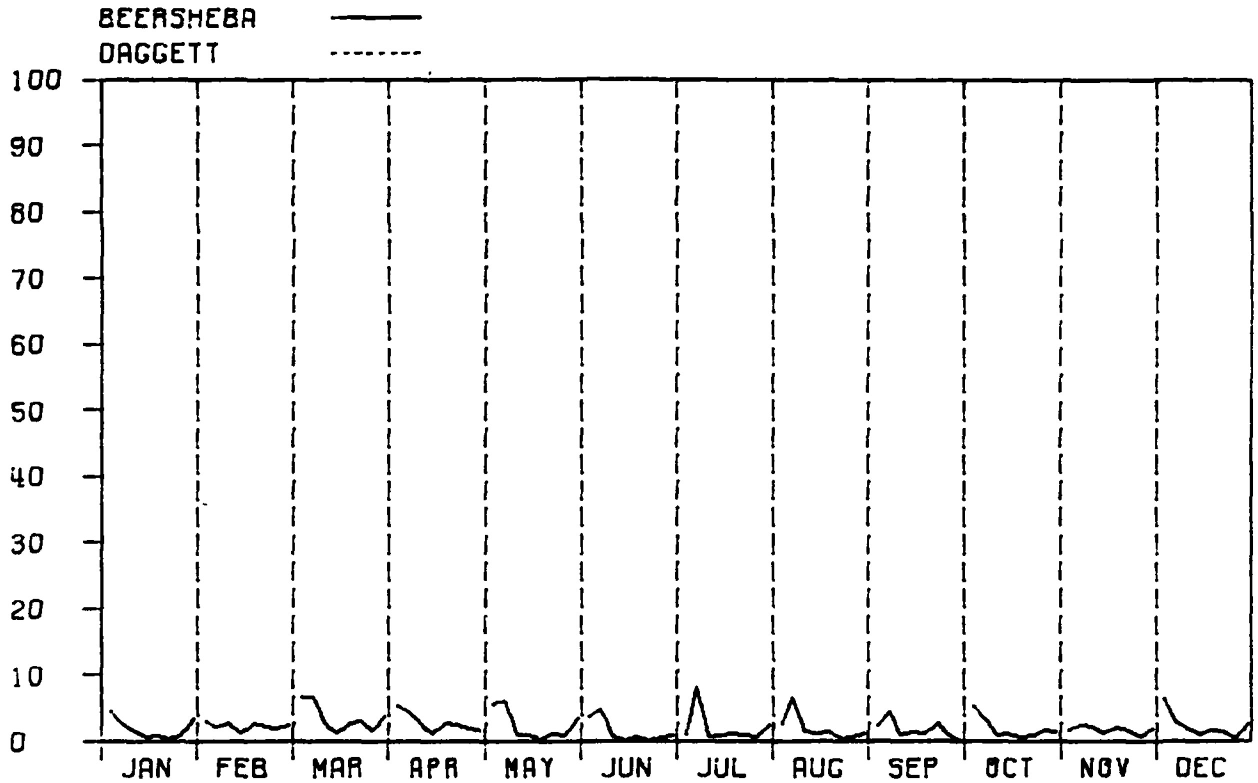
Fig. 21 shows the average monthly frequencies of lowest cloud height for the five layers for each station (again, no data for Daggett). In the lowest layer (0-49 m) the annual average frequency at Beersheba is about 2% of the observation times with a peak of about 3.5% in March. The frequencies in the 50-199 m layer for all stations are all less than 2%.

The shapes of the mean monthly curves in the 200-999 m layer are all quite similar with a minimum in spring and a maximum in winter. The Beersheba curve is higher than the other curves by about 20%. The plot for the next higher layer (1000-2499 m) shows the effect of nearby mountains in increasing the frequencies during the warm season at El Paso and Ft. Huachuca. The annual curve for Beersheba is quite flat, varying by about 8% from the minimum to the maximum.

One can subtract the clear sky frequencies in Fig. 18 from the respective frequencies with lowest cloud height layer $\geq$2500 m or no clouds to get an estimate of the frequency of heights $\geq$2500 m. The clear sky frequencies are approximately the no cloud frequencies. The result is that for all

stations most of the magnitude of any frequency in the $\geq$2500 m class is actually the no cloud condition.

Fig. 20. LOWEST CLOUD HT - METERS
CLASS = 0 - 49
FREQUENCY (IN PER CENT). BY 3-HOURLY PERIOD AND BY MONTH



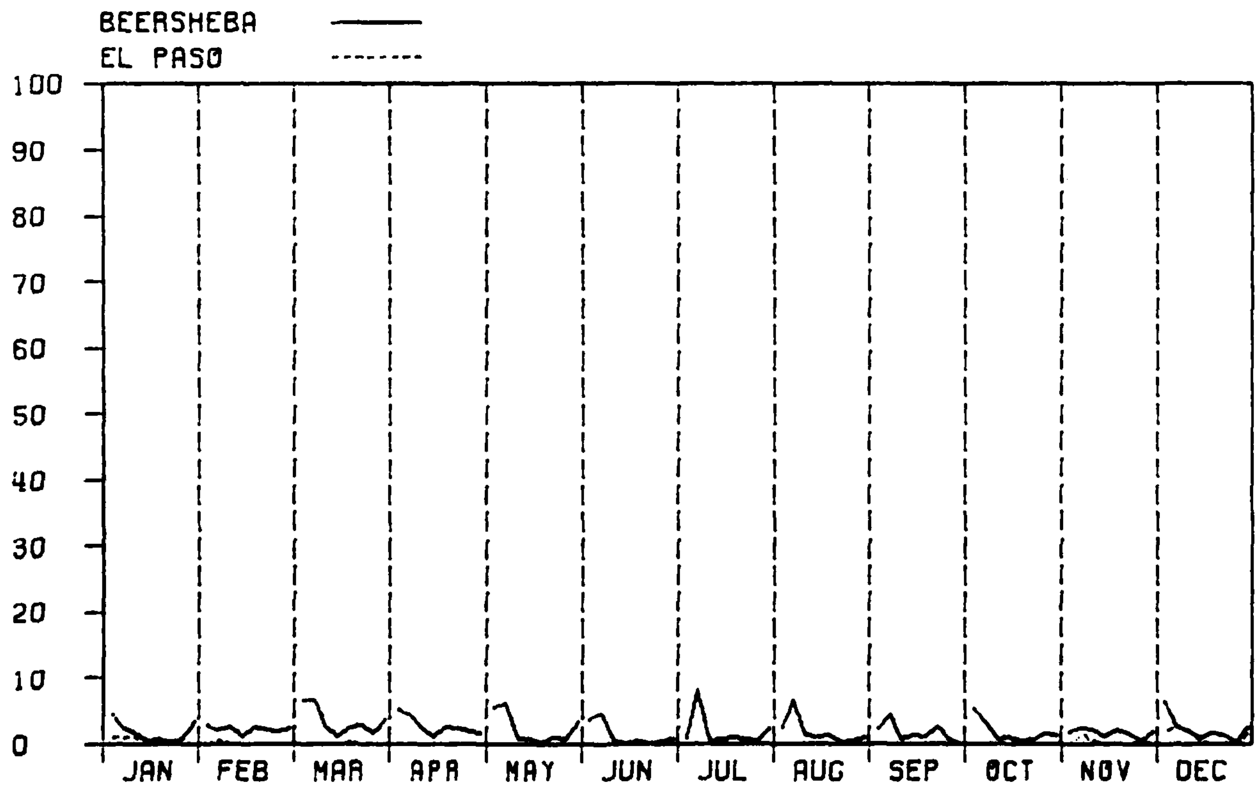
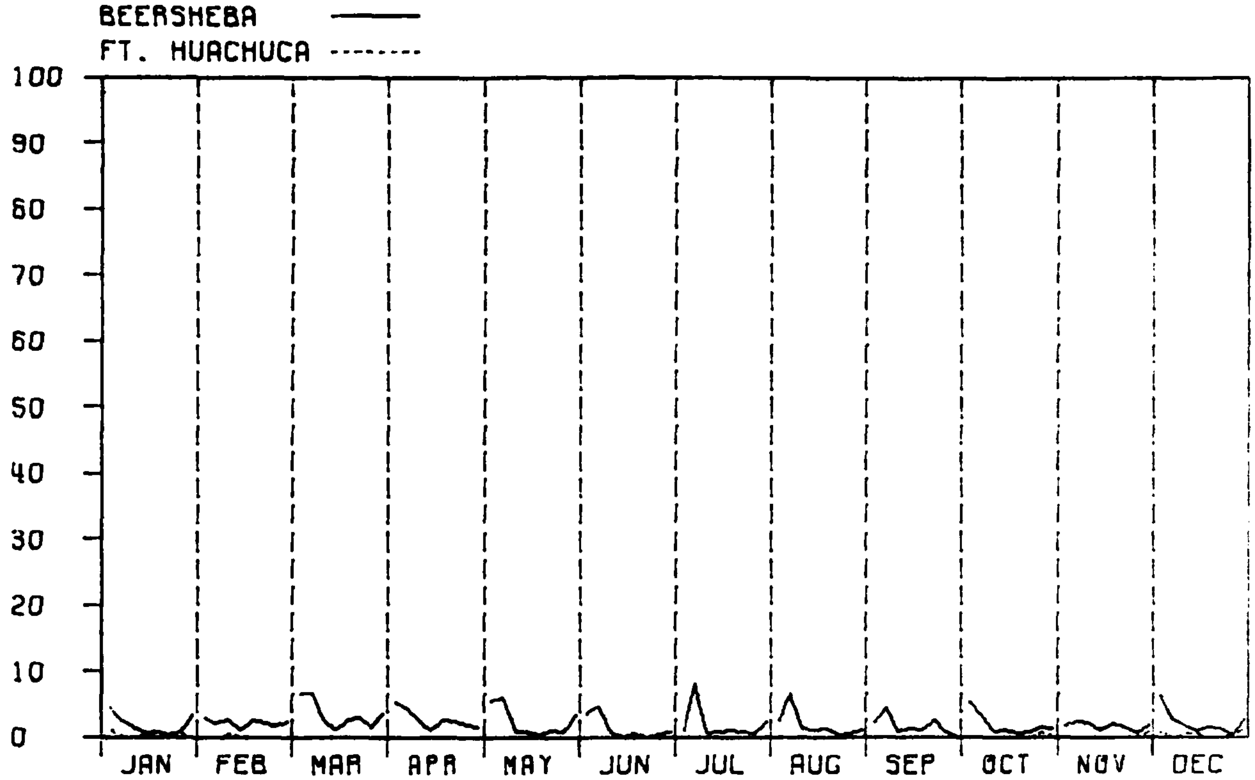



Fig. 20. (Cont'd) LOWEST CLOUD HT - METERS
CLASS = 0 - 49
FREQUENCY (IN PER CENT), BY 3-HOURLY PERIOD AND BY MONTH



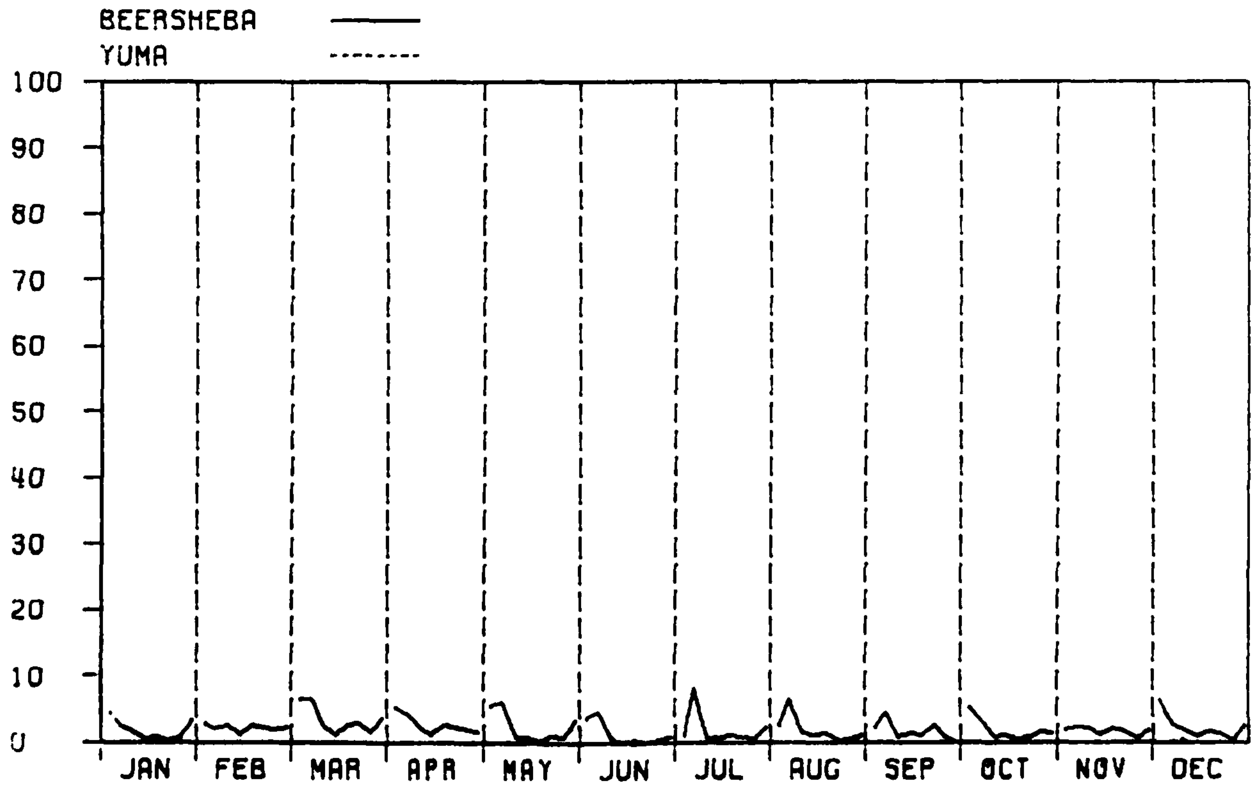
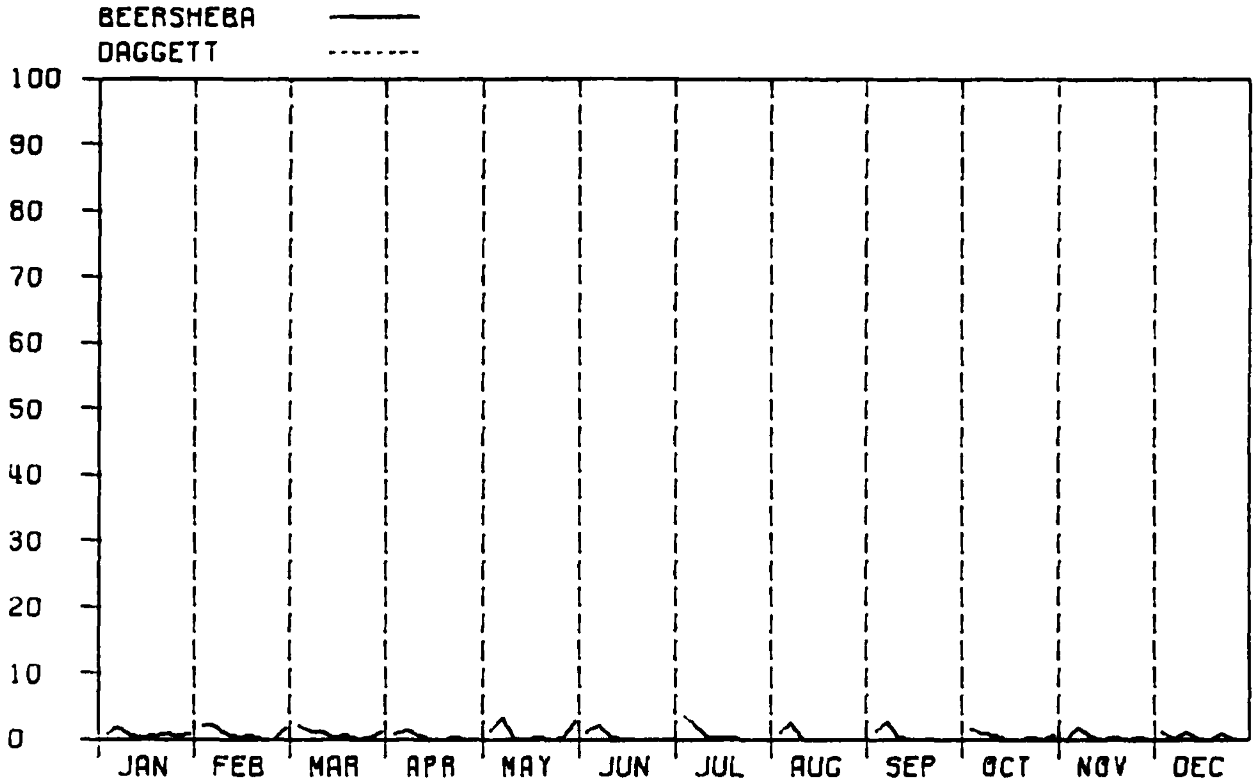



Fig. 20. (Cont'd) LOWEST CLOUD HT - METERS
CLASS = 50 - 199
FREQUENCY (IN PER CENT). BY 3-HOURLY PERIOD AND BY MONTH



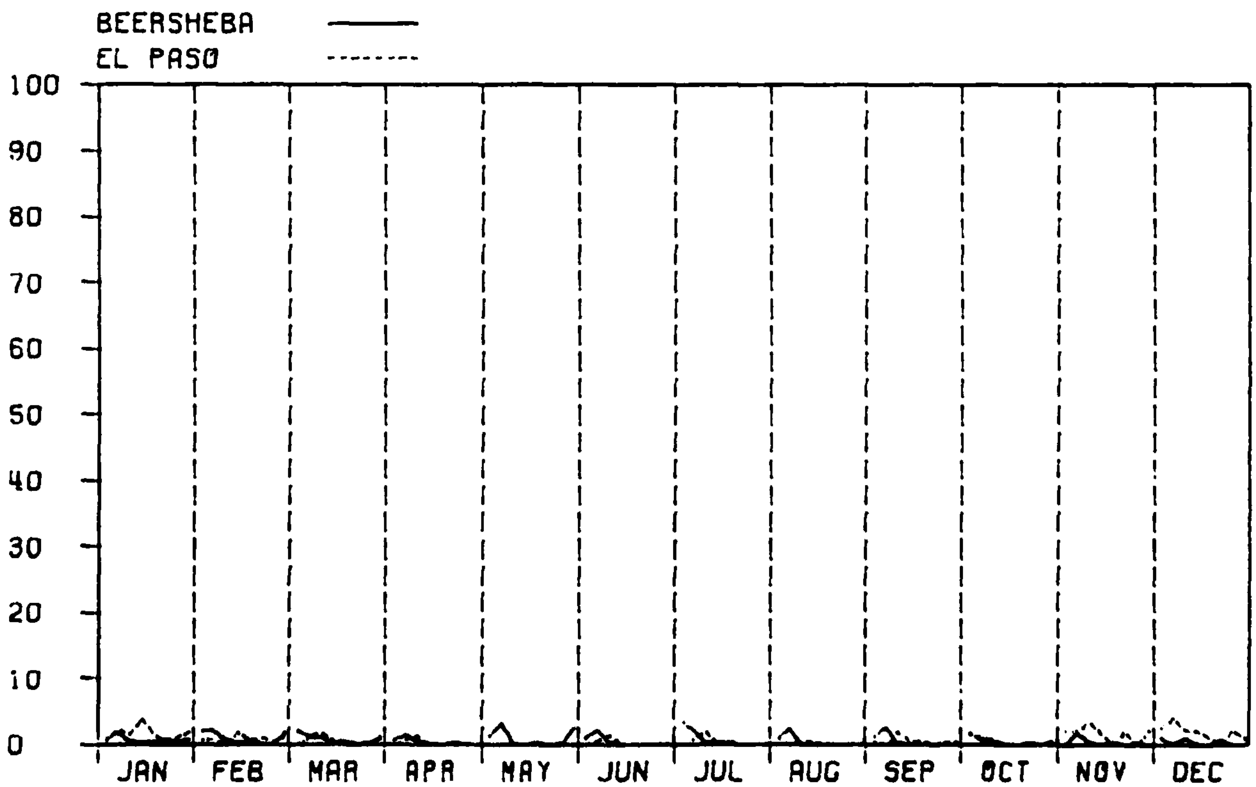
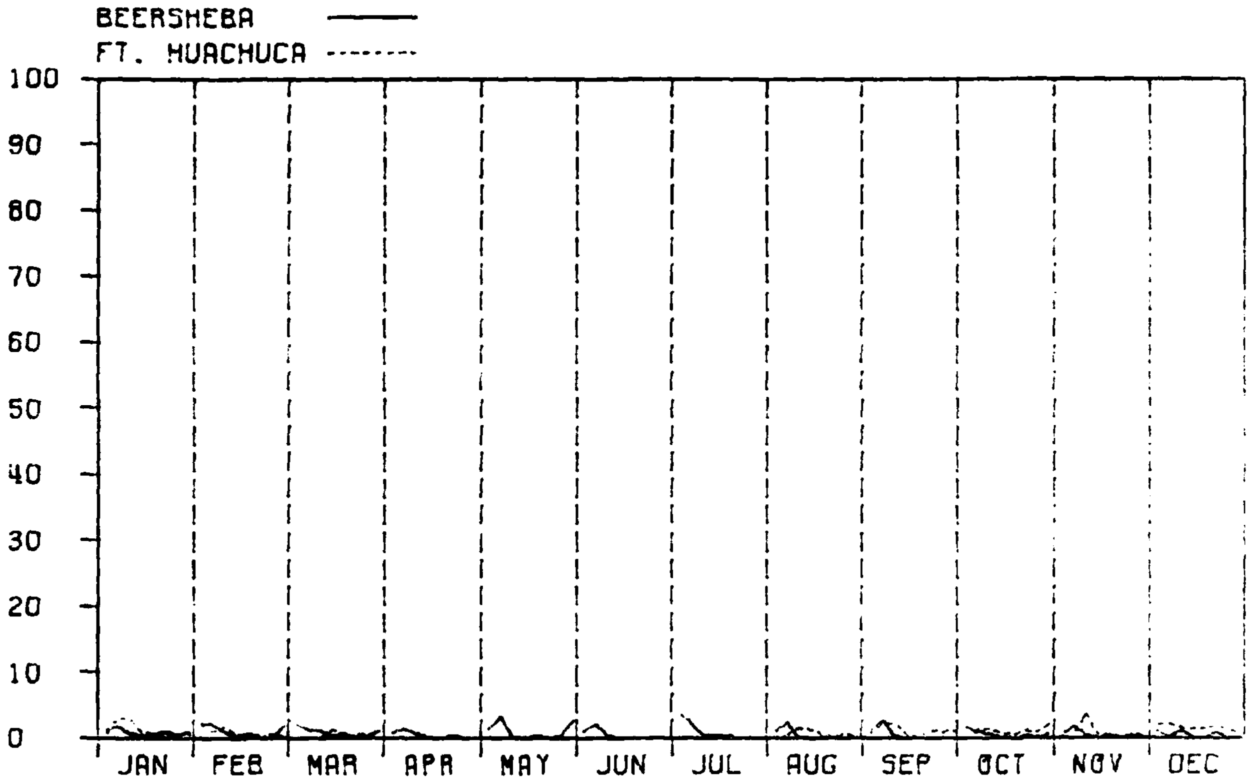



Fig. 20. (Cont'd) LOWEST CLOUD HT - METERS

CLASS = 50 - 199

FREQUENCY (IN PER CENT), BY 3-HOURLY PERIOD AND BY MONTH



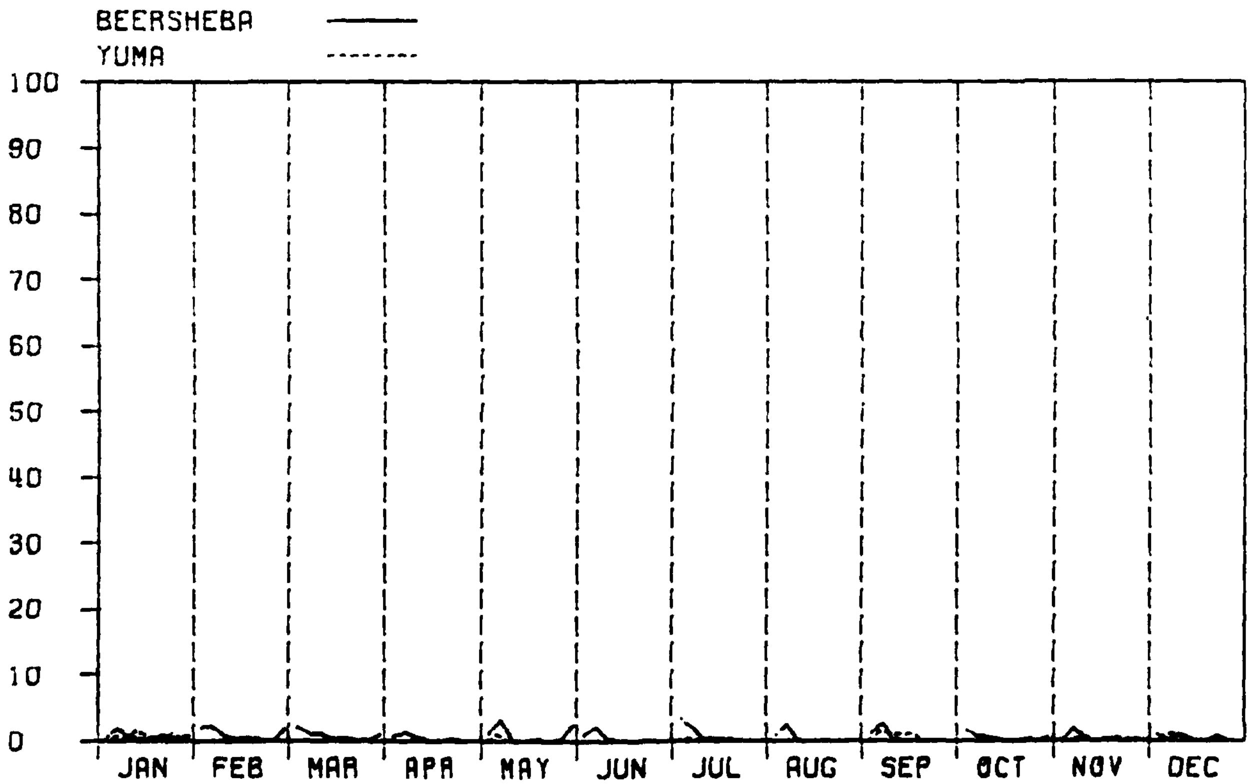
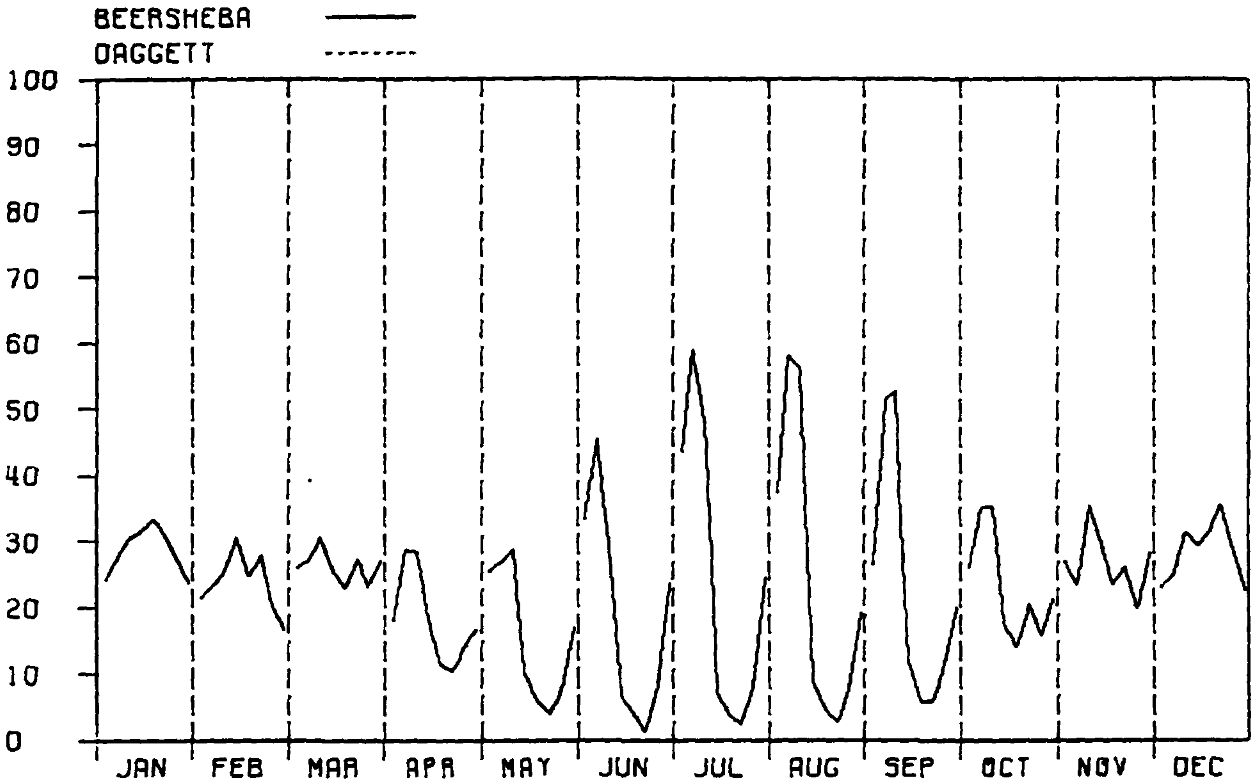



Fig. 20. (Cont'd) LOWEST CLOUD HT - METERS
CLASS = 200 - 999
FREQUENCY (IN PER CENT). BY 3-HOURLY PERIOD AND BY MONTH



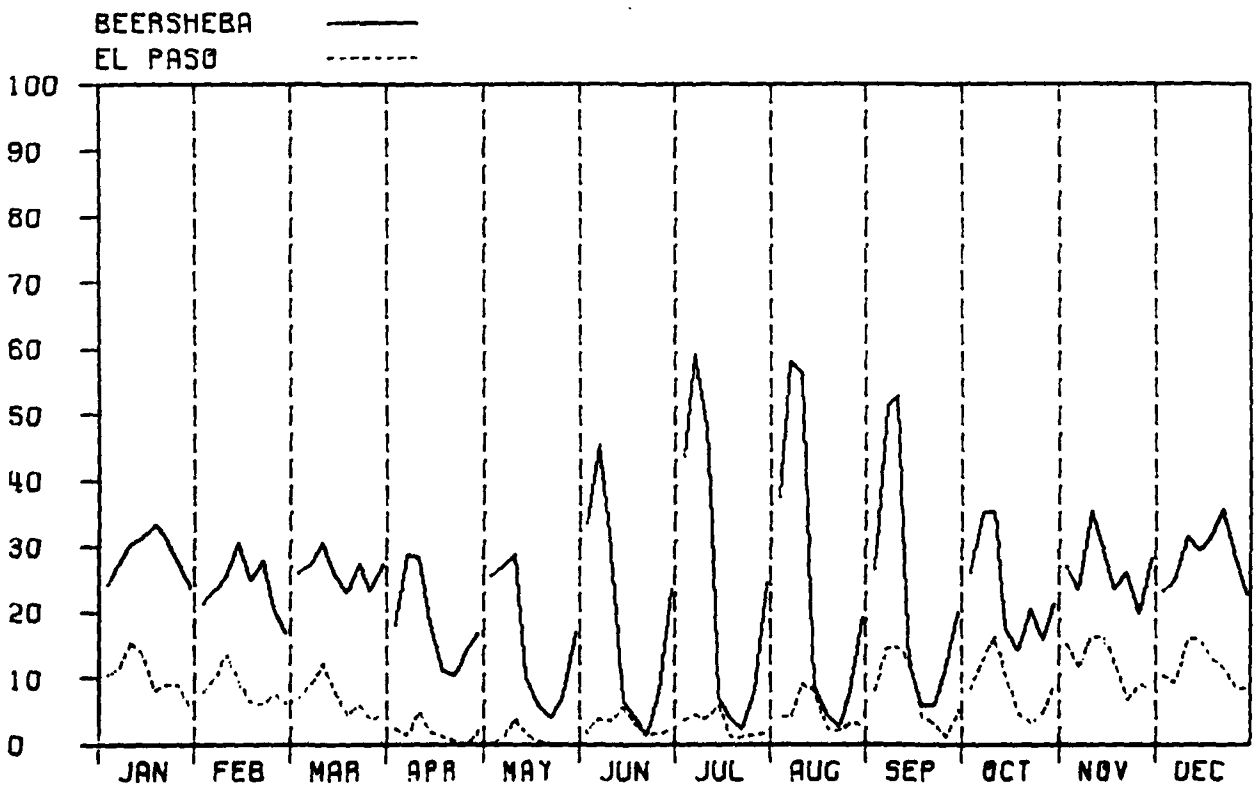
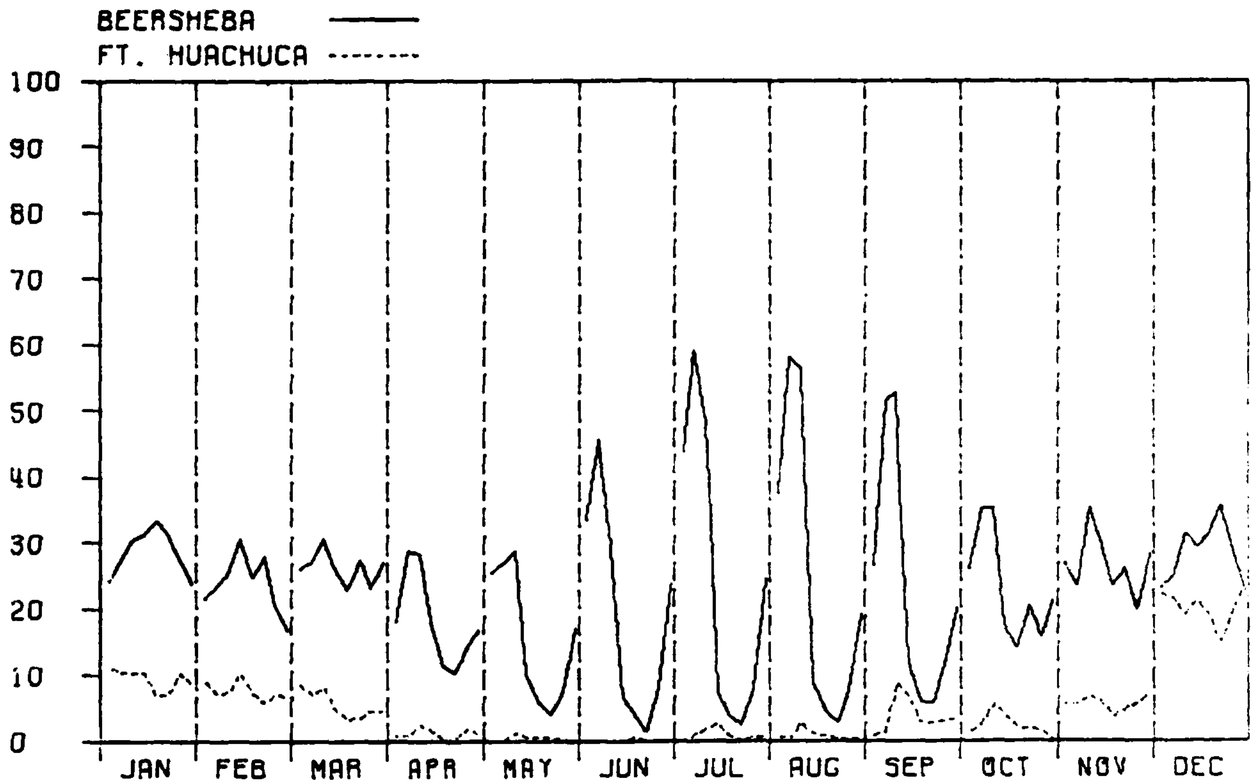



Fig. 20. (Cont'd) LOWEST CLOUD HT - METERS
CLASS = 200 - 999
FREQUENCY (IN PER CENT). BY 3-HOURLY PERIOD AND BY MONTH



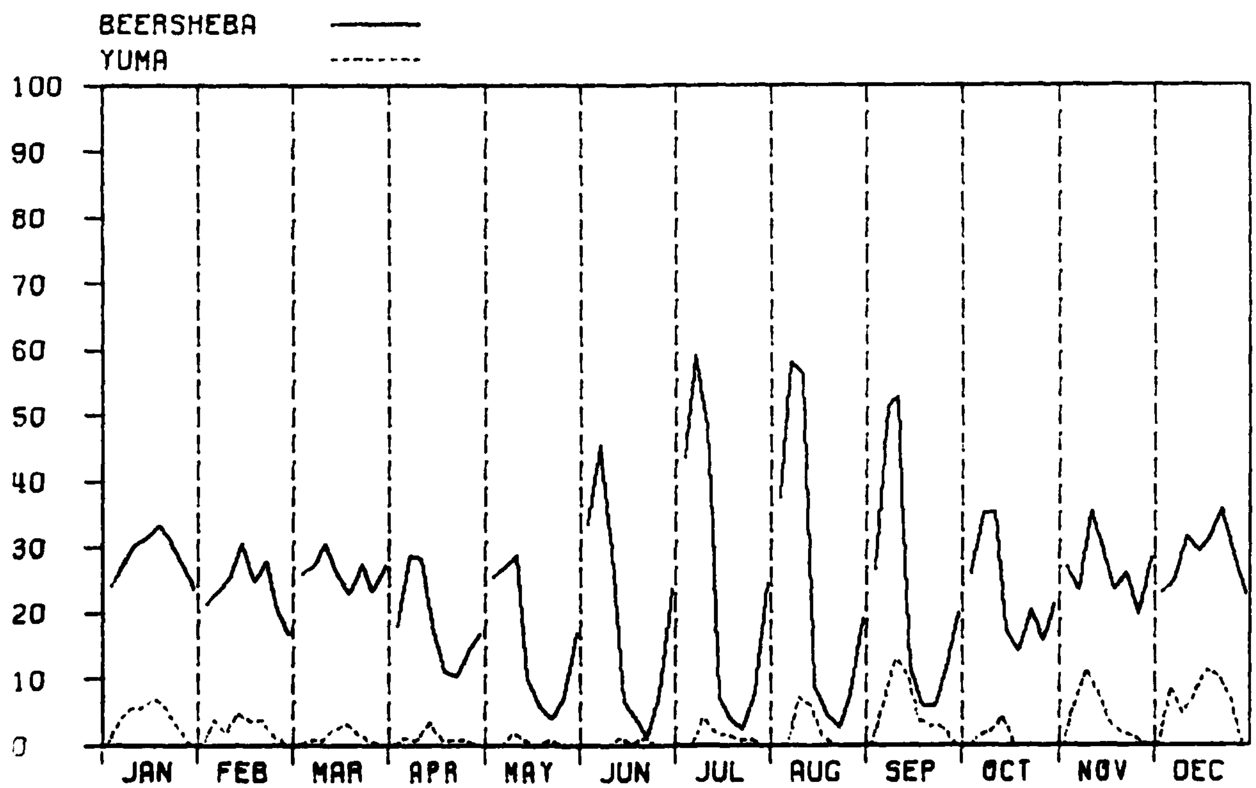
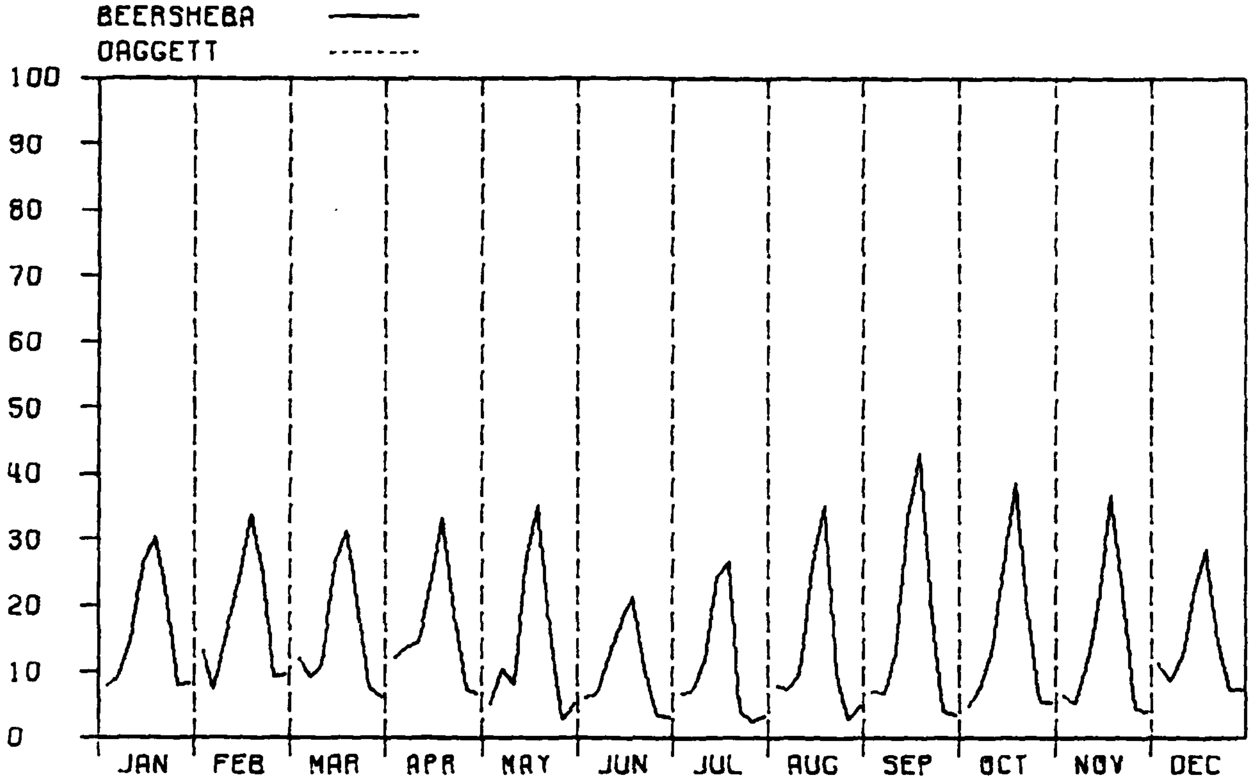



Fig. 20. (Cont'd) LOWEST CLOUD HT - METERS
CLASS = 1000 - 2499
FREQUENCY (IN PER CENT). BY 3-HOURLY PERIOD AND BY MONTH



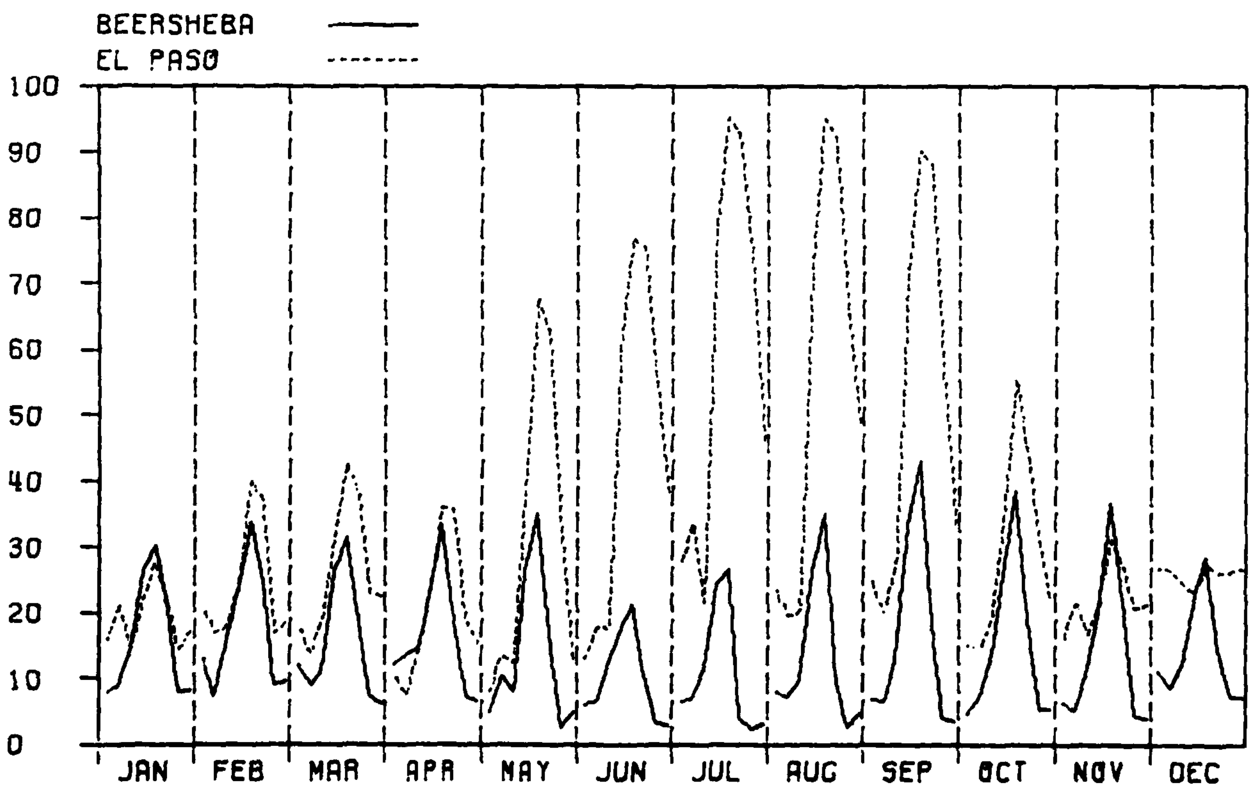
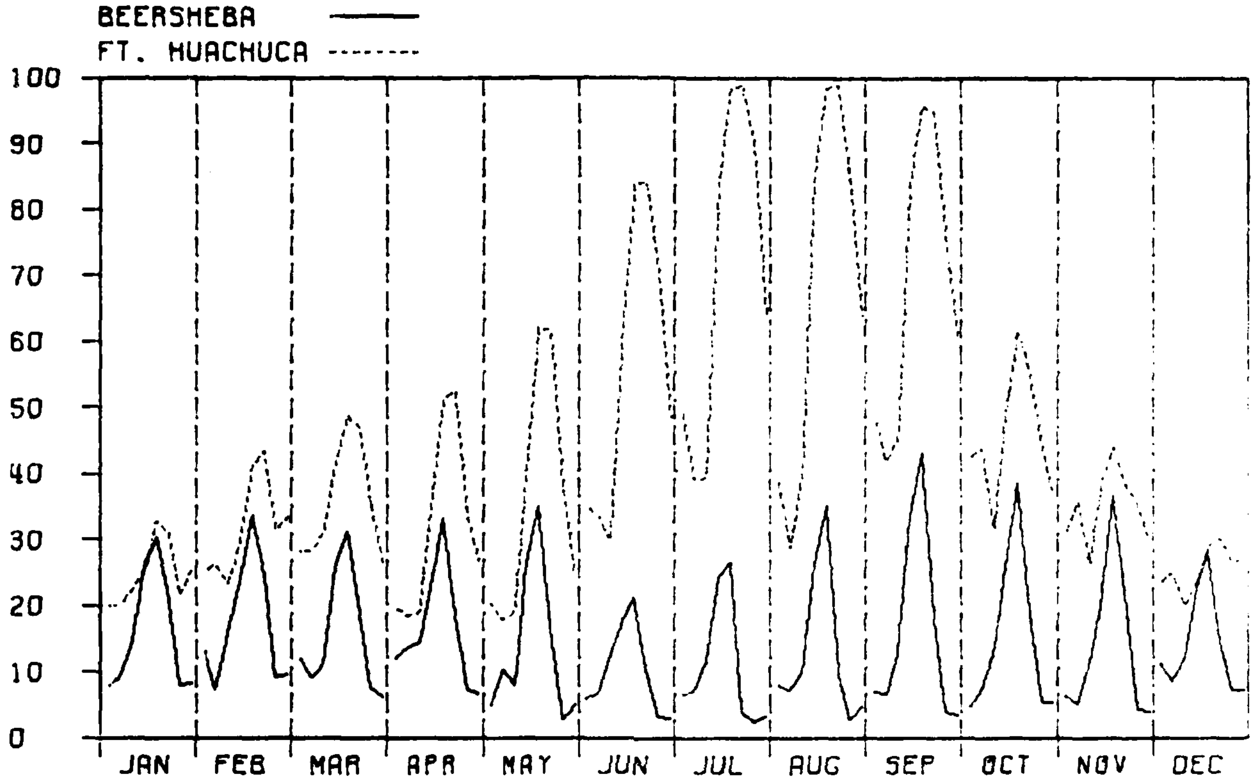



Fig. 20. (Cont'd) LOWEST CLOUD HT - METERS
CLASS = 1000 - 2499
FREQUENCY (IN PER CENT). BY 3-HOURLY PERIOD AND BY MONTH



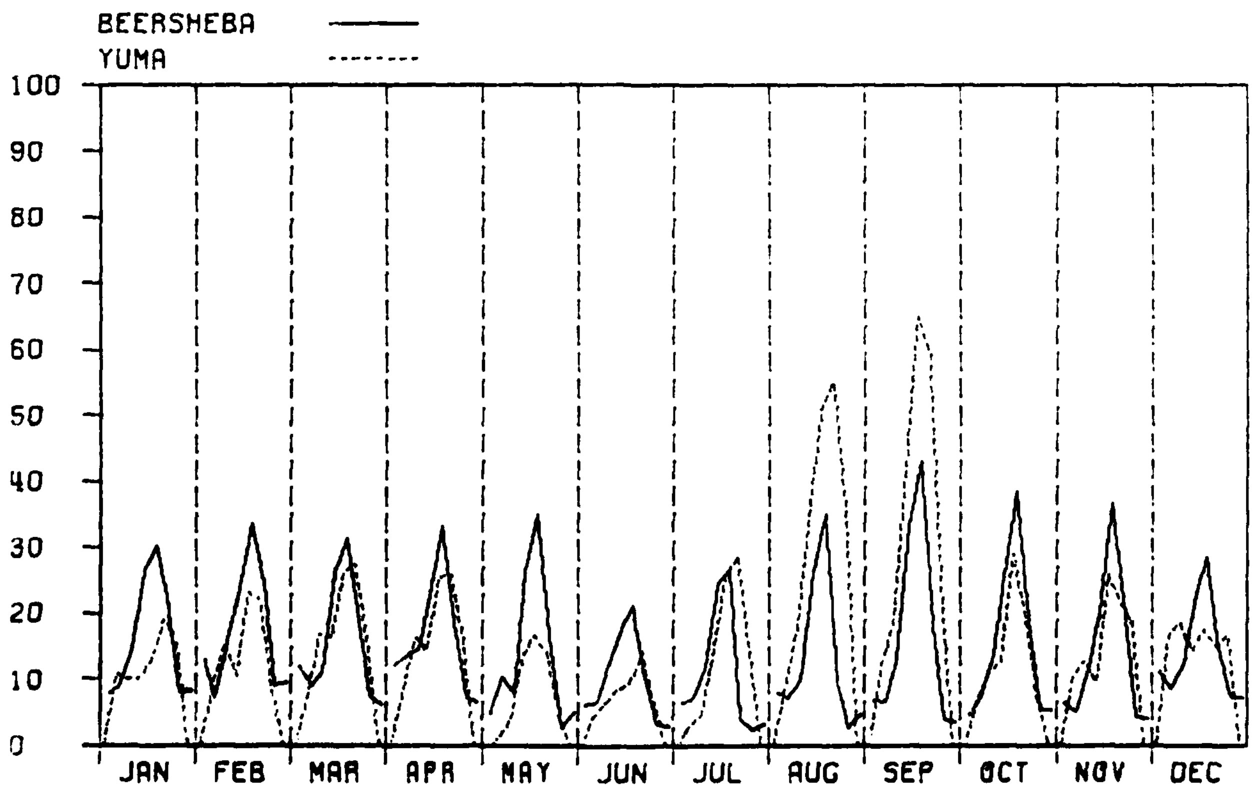
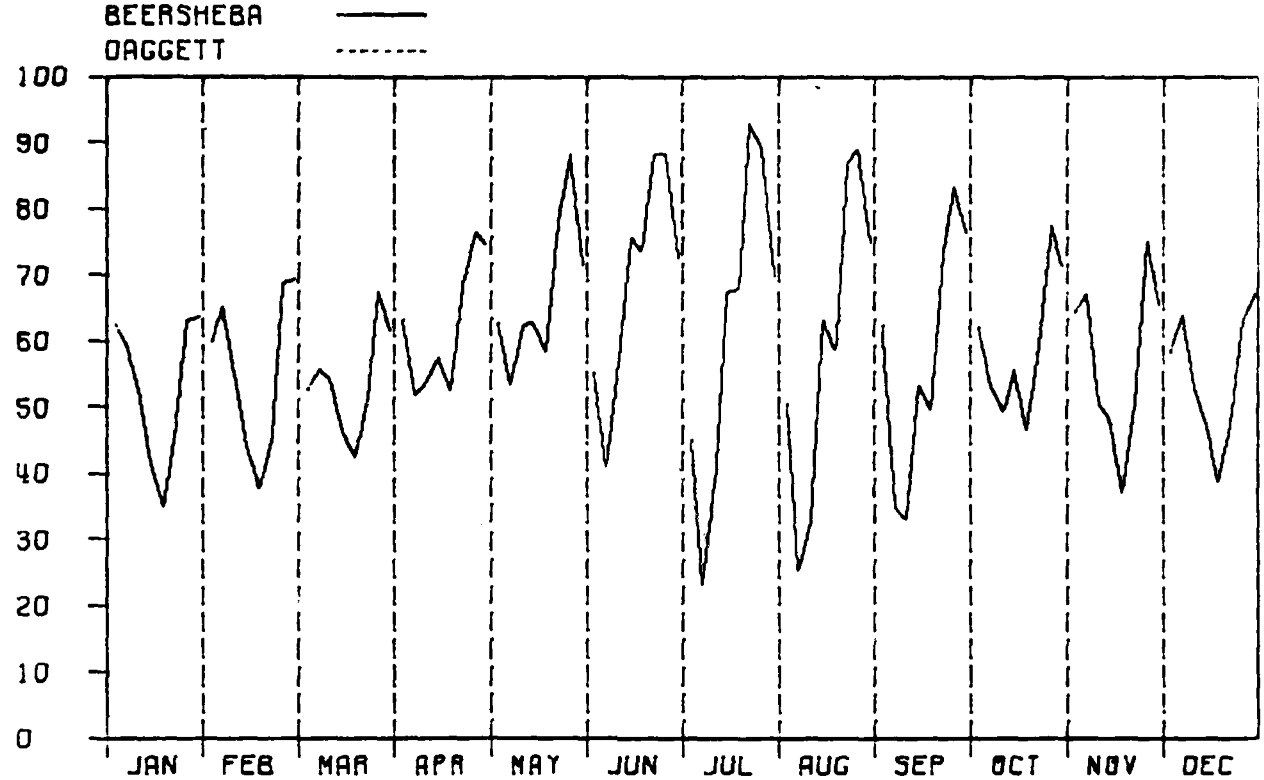



Fig. 20. (Cont'd) LOWEST CLOUD HT - METERS
CLASS = => 2500
FREQUENCY (IN PER CENT), BY 3-HOURLY PERIOD AND BY MONTH



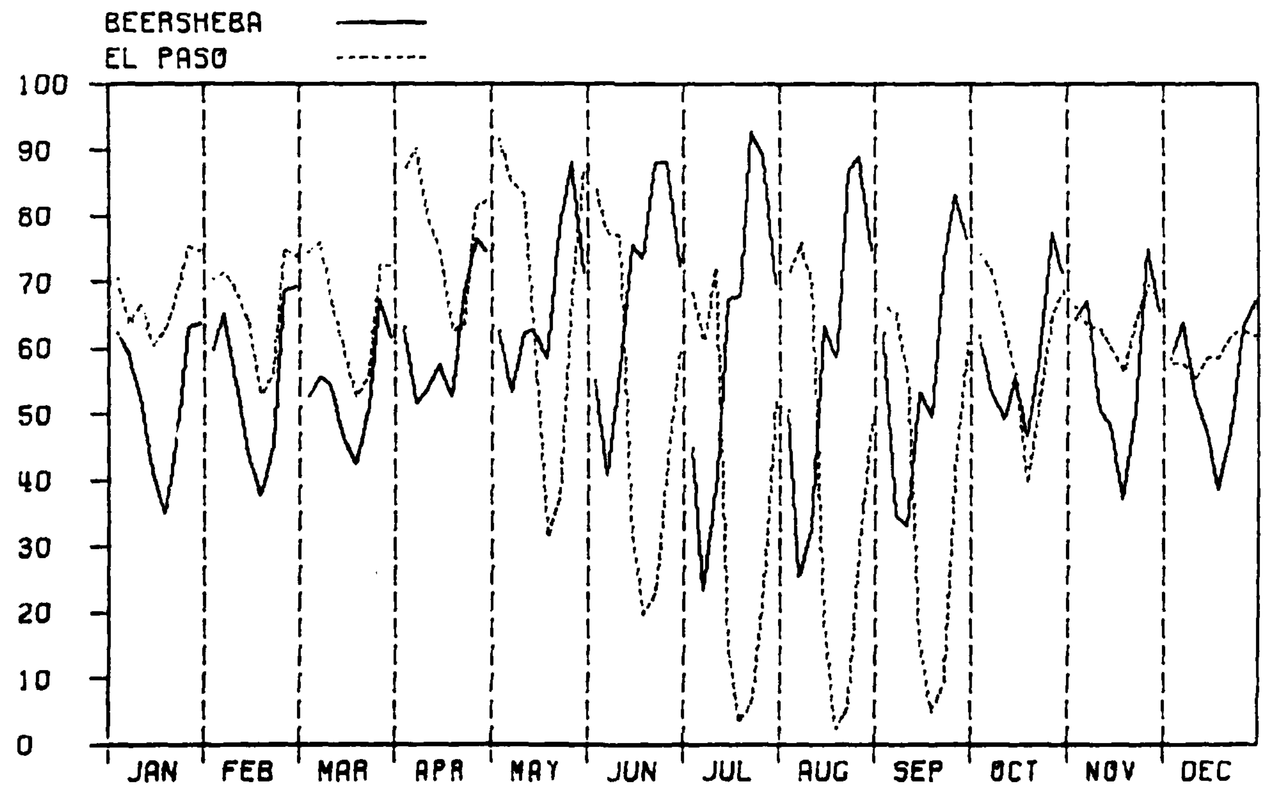



Fig. 20. (Cont'd) LOWEST CLOUD HT - METERS
CLASS = => 2500
FREQUENCY (IN PER CENT). BY 3-HOURLY PERIOD AND BY MONTH

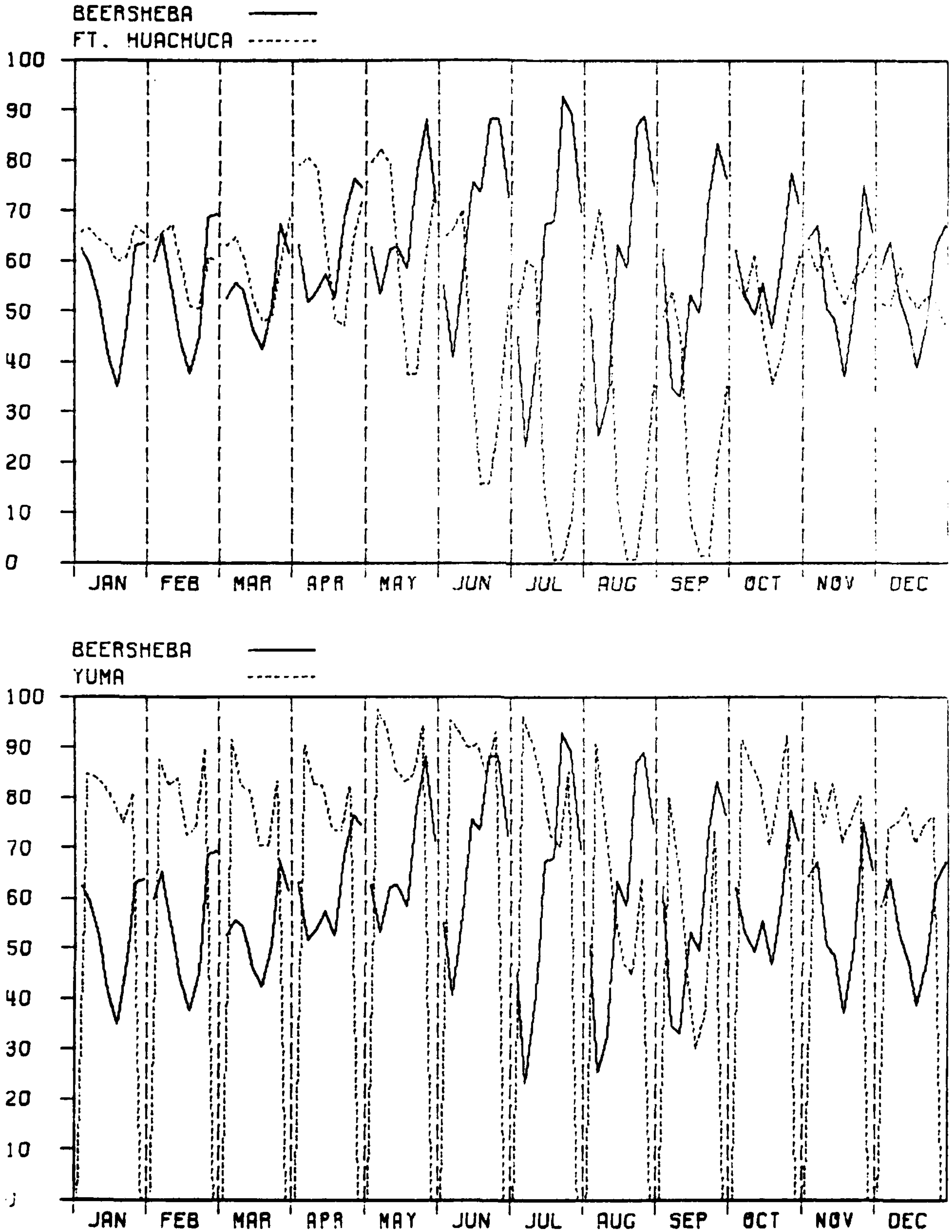


Fig. 21. LOWEST CLOUD HT - METERS
CLASS = 0 - 49
FREQUENCY (IN PER CENT). BY MONTH

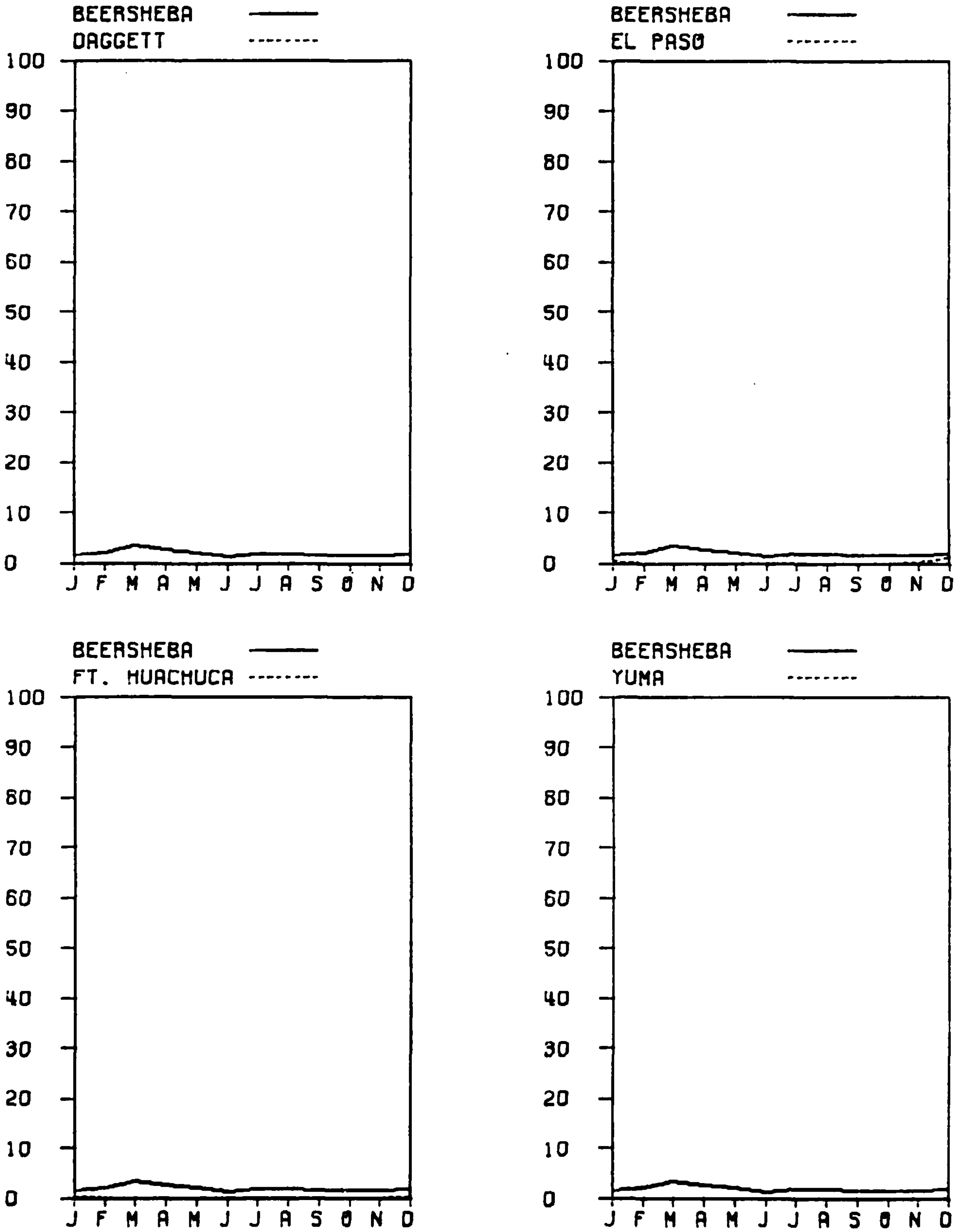


Fig. 21. (Cont'd) LOWEST CLOUD HT - METERS
CLASS = 50 - 199
FREQUENCY (IN PER CENT), BY MONTH

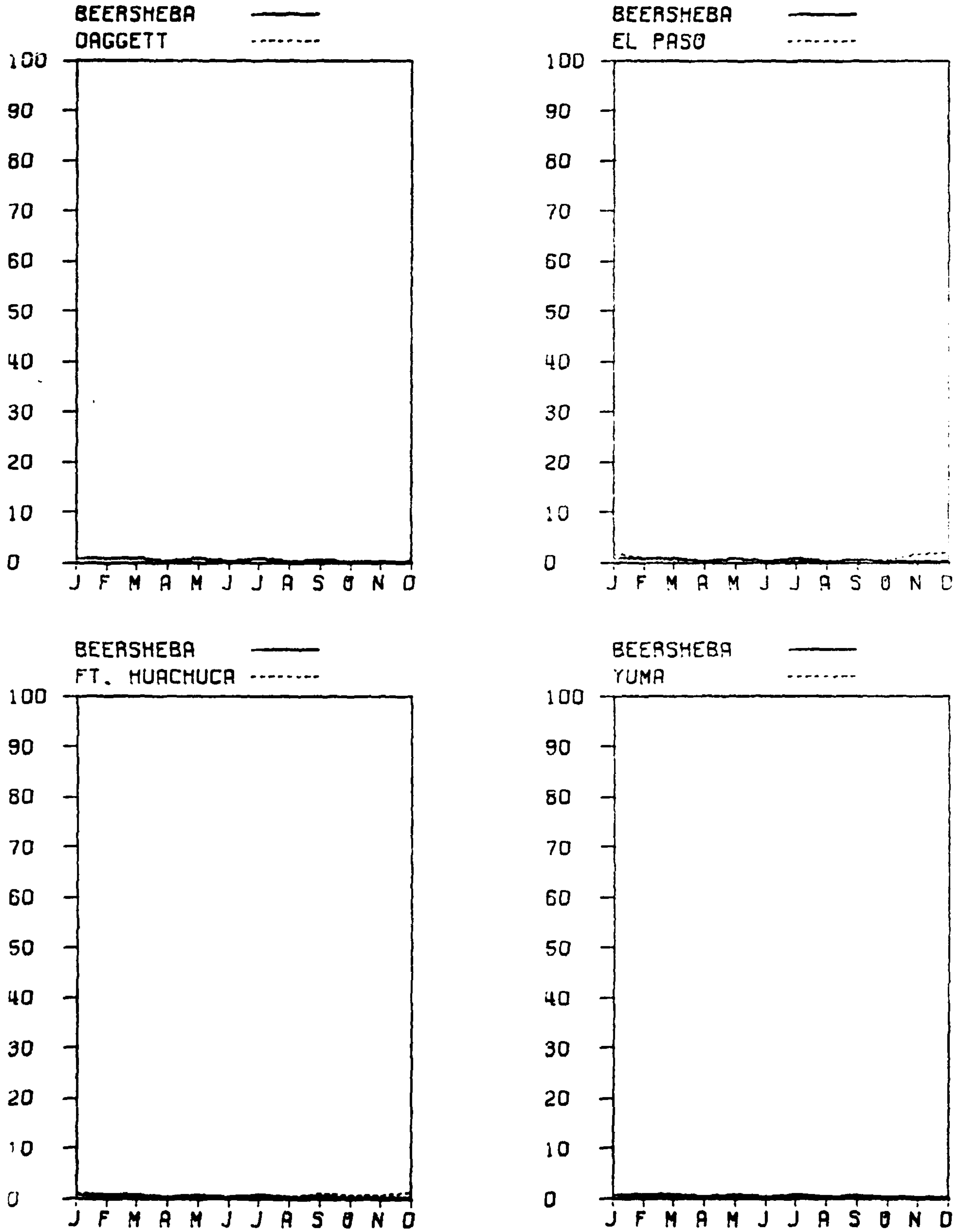


Fig. 21. (Cont'd) LOWEST CLOUD HT - METERS
CLASS = 200 - 999
FREQUENCY (IN PER CENT). BY MONTH

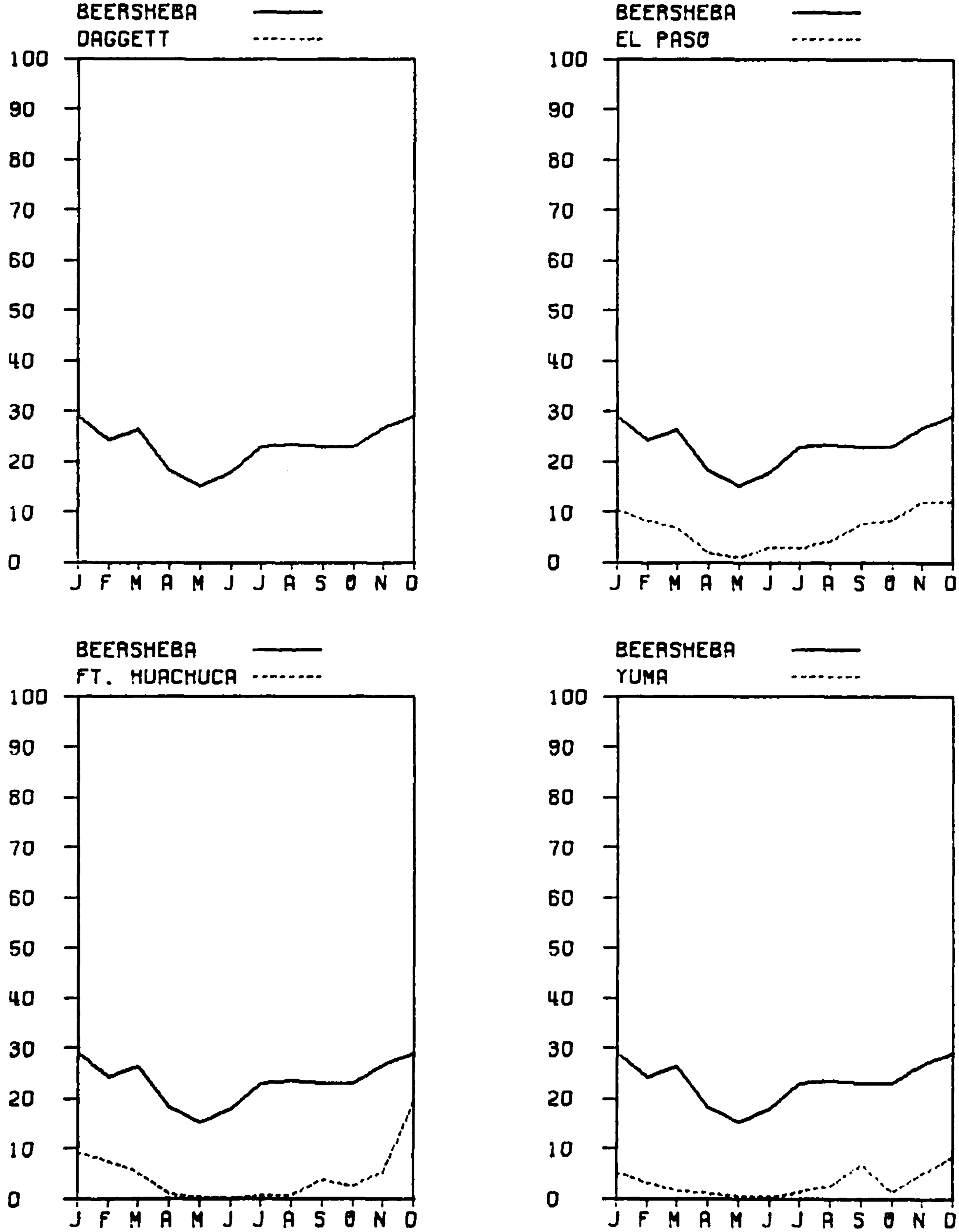


Fig. 21. (Cont'd) LOWEST CLOUD HT - METERS
CLASS = 1000 - 2499
FREQUENCY (IN PER CENT), BY MONTH

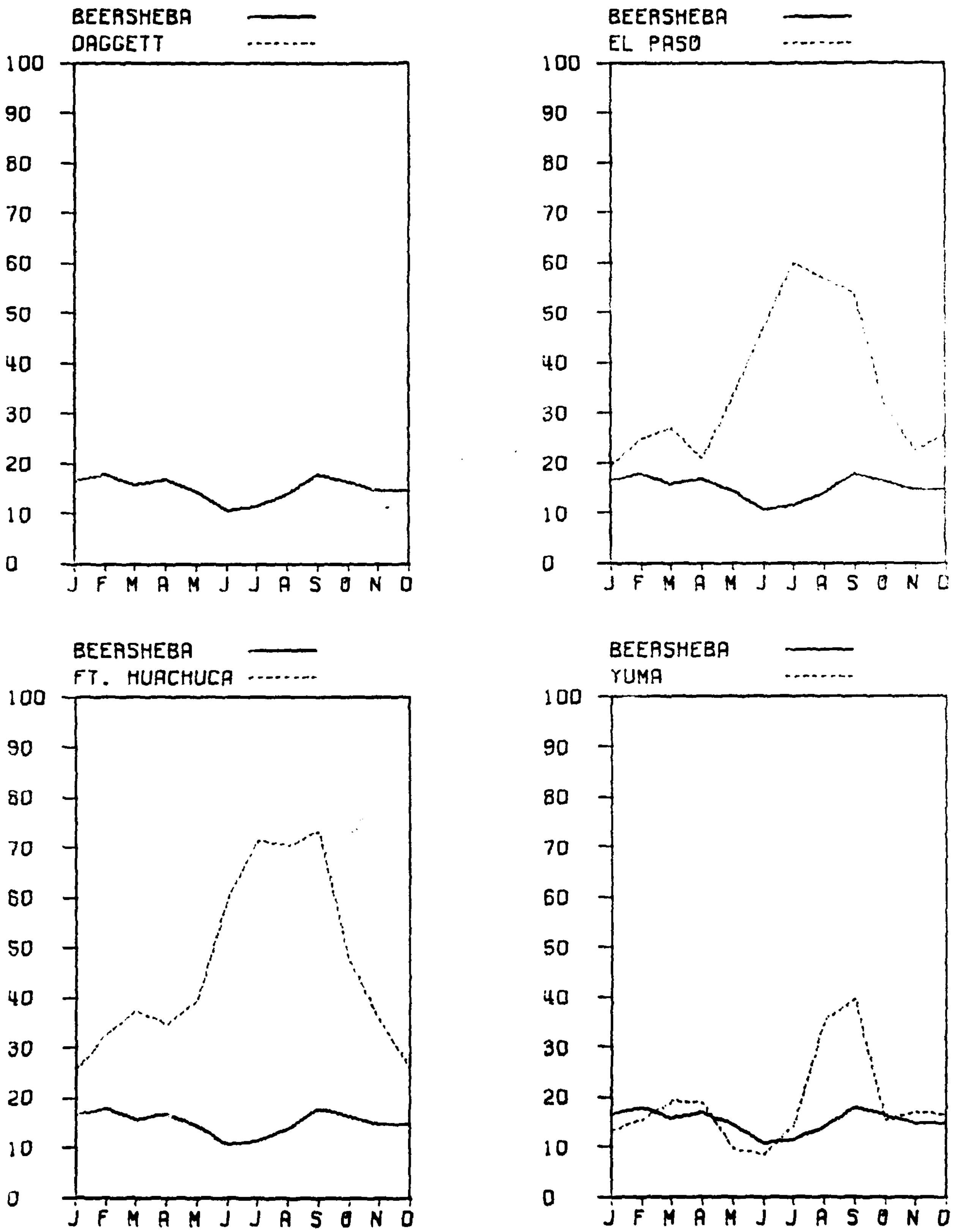
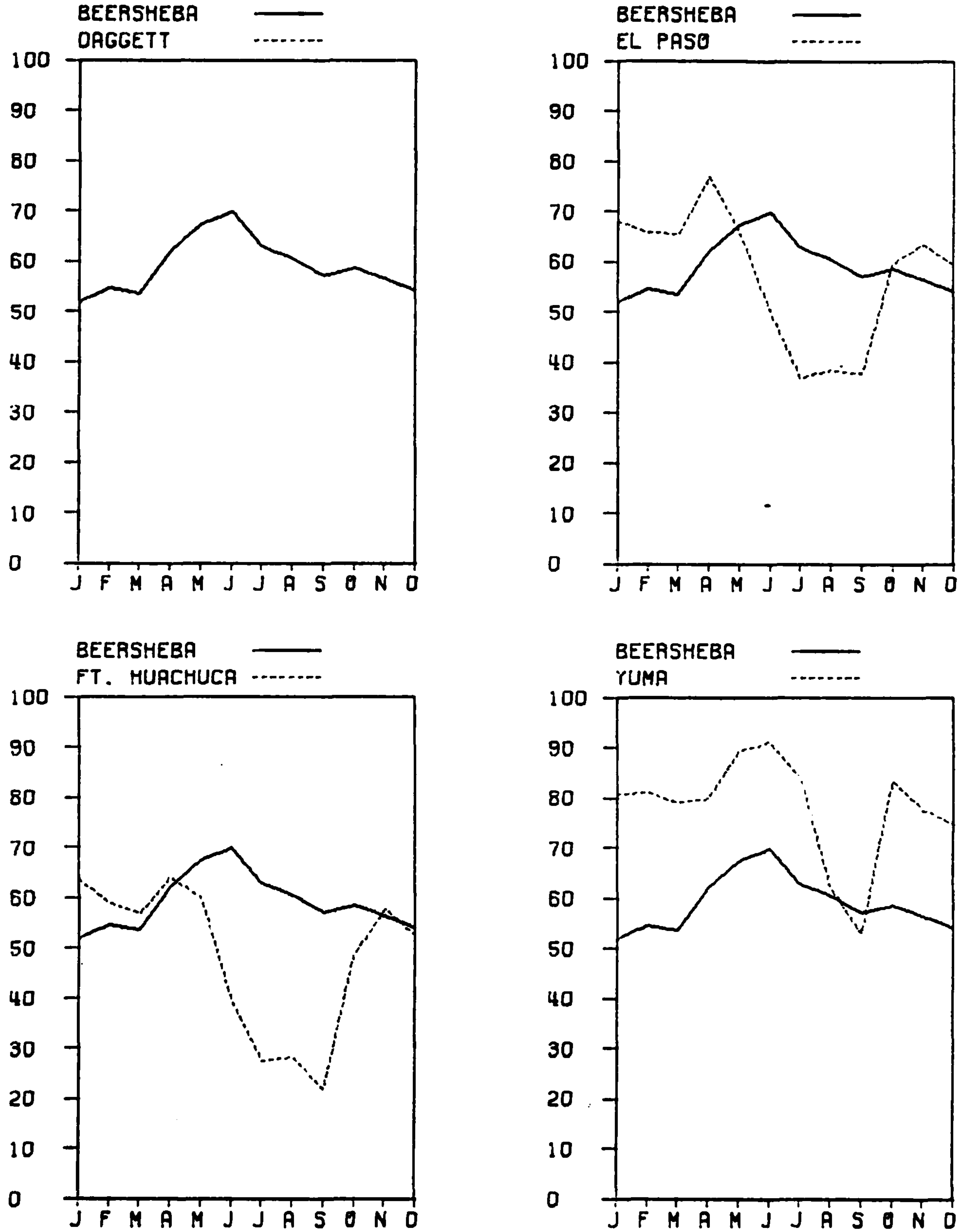


Fig. 21. (Cont'd) LOWEST CLOUD HT - METERS
CLASS = => 2500
FREQUENCY (IN PER CENT) , BY MONTH



## C. Ceiling Height

### 1. Method of Computation

Ceiling height, or simply ceiling, is the height above ground of the base of the lowest cloud layer whose amount is 5/8 or greater for the Synoptic Code and 6/10 or greater for the Airways Code. The way the ceiling was processed for the Beersheba data requires some explanation. The original Beersheba data tape did not contain ceiling information. The data tape that was processed in this study contained a ceiling created by using the fraction of the celestial dome covered and the height of the lowest cloud. The fraction referred to in the former variable applies to the low clouds present and, if no low cloud is present, the fraction covered by all the middle clouds present. If the fraction was >4/8 then the lowest height became the ceiling. If the fraction was ≤4/8 the ceiling was set to zero.

There are at least two aspects of this procedure that should be examined. Firstly, the zero ceiling, according to the Synoptic Code for lowest cloud height, would mean a height of from 0 to 49 m. Thus the coded value of zero for ceiling could mean that the ceiling is 0-49 m, within or above the middle cloud layer, or was unlimited (no ceiling). Secondly, if the fraction of the celestial dome covered was >4/8 and the reported lowest cloud height was 2500 m, then the ceiling is 2500 m or higher (but in the middle cloud layer).

At best the method described above provides a reasonable estimate of the ceiling height at Beersheba when it is in the low cloud layer between 50 and 2500 m. The Airways Code gives the ceiling in hundreds of feet, similar to lowest cloud height. In order to make the ceiling heights compatible for all stations each ceiling height for the U.S. stations was placed into one of four categories:

| Category | Observed Ceiling |
|---|---|
| 0-49 m | 0-49 m, or $\geq$2000 m, or unlimited |
| 50-199 m | 50-199 m |
| 100-999 m | 200-999 m |
| 1000-1999 m | 1000-1999 m |

2. Comparative Analysis

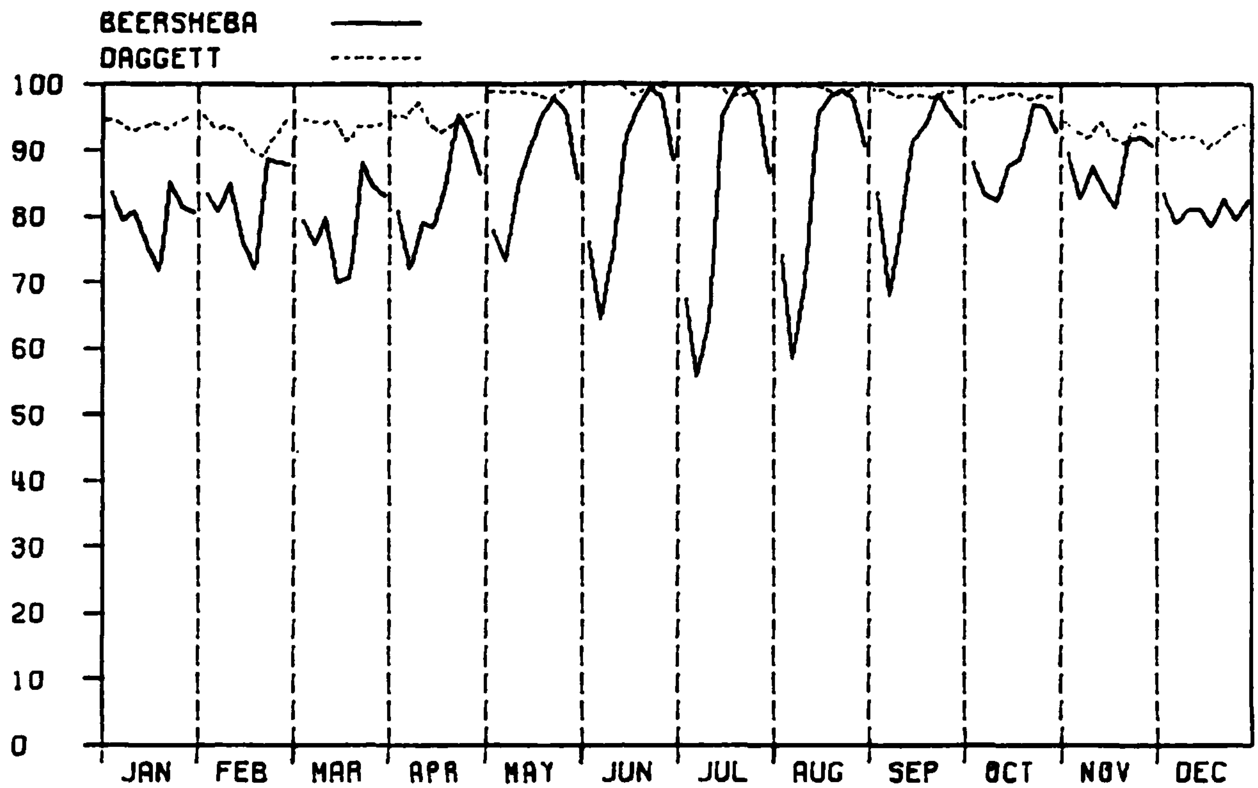
Fig. 22 shows the frequency of occurrence of the 3-hourly ceiling height by month. The plots for the 0-49 m layer show that for any station most of the ceilings are above 2000 m including unlimited. This is because in Fig. 20 for lowest cloud height the frequencies for the 0-49 m layer are all very small so that, of course, the frequency of ceilings in the layer must be the same or smaller.

For a given layer at Beersheba, each frequency of ceiling height is some fraction of the associated frequency of lowest cloud height due to the method of computation. This is true also for the U.S. stations in the lower layers. If

layers higher than 1000-1999 m were analyzed, this relationship need not hold. This is because the ceiling can occur only at or above the lowest cloud height and not below.

The monthly frequencies of ceiling height are presented in Fig. 23. It is interesting that the Beersheba frequencies for the 50-199 m layer closely correspond to lowest cloud height frequencies for this layer (see Fig. 21). This means that whenever there are cloud bases in this layer, the clouds are usually broken or overcast. The ratio of the ceiling height frequencies to the lowest cloud height frequencies in the 200-999 m layer varies from about 0.4 to 0.6 at Beersheba. The range in ratio for U.S. stations has little meaning because there are practically no clouds in this layer during the summer.

Fig. 22. CEILING HEIGHT - METERS
CLASS = 0 - 49
FREQUENCY (IN PER CENT). BY 3-HOURLY PERIOD AND BY MONTH



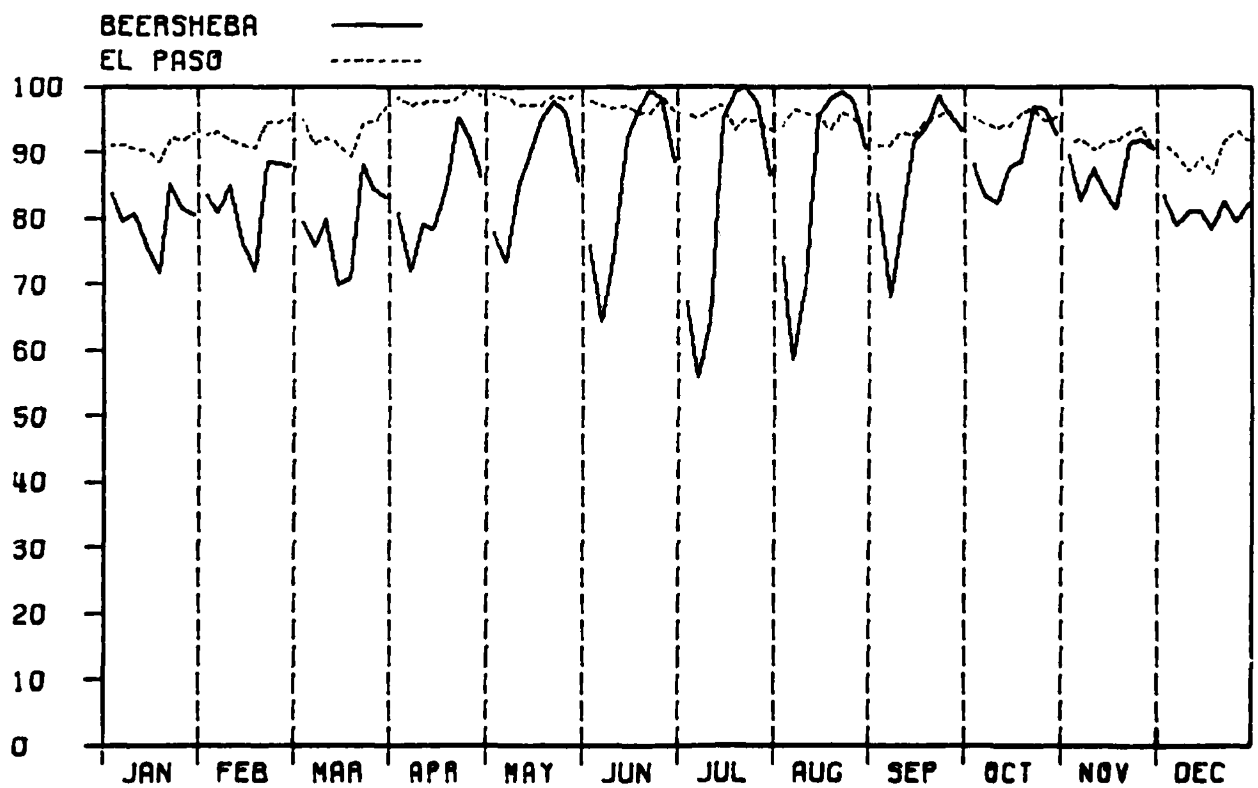
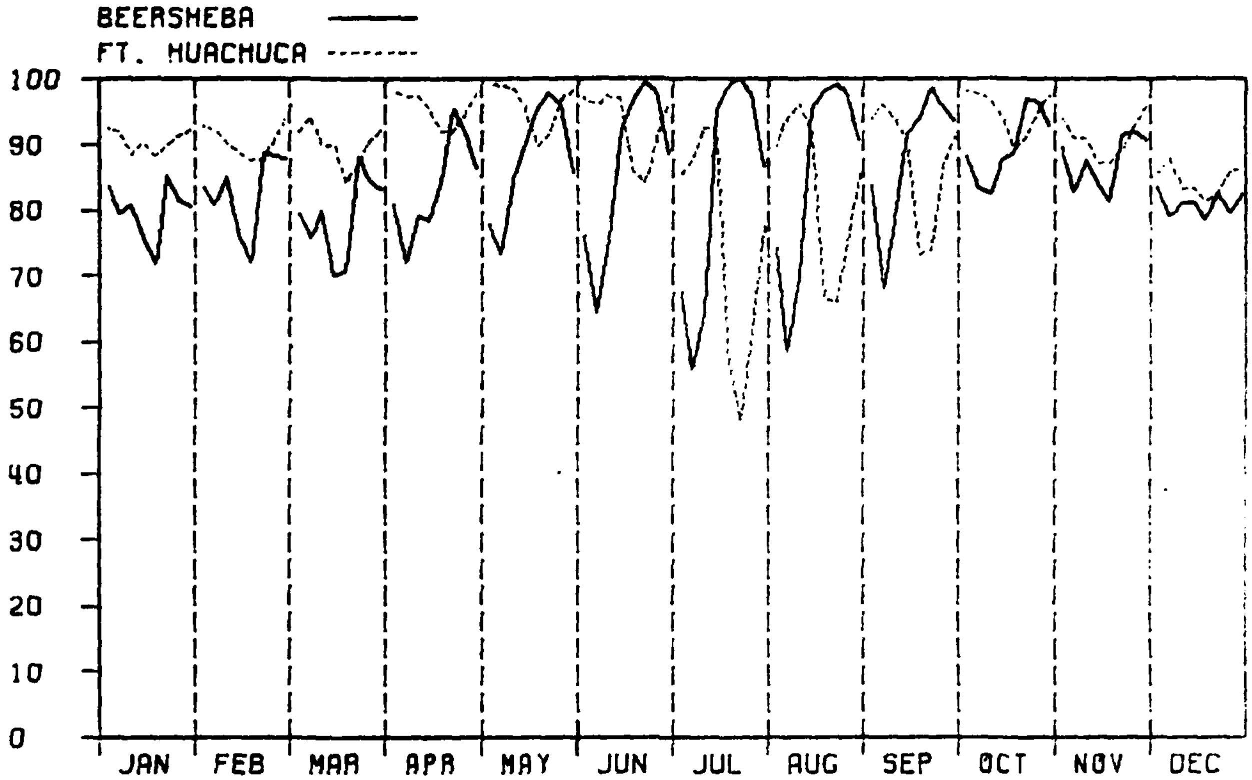



Fig. 22. (Cont'd) CEILING HEIGHT - METERS
CLASS = 0 - 49
FREQUENCY (IN PER CENT), BY 3-HOURLY PERIOD AND BY MONTH



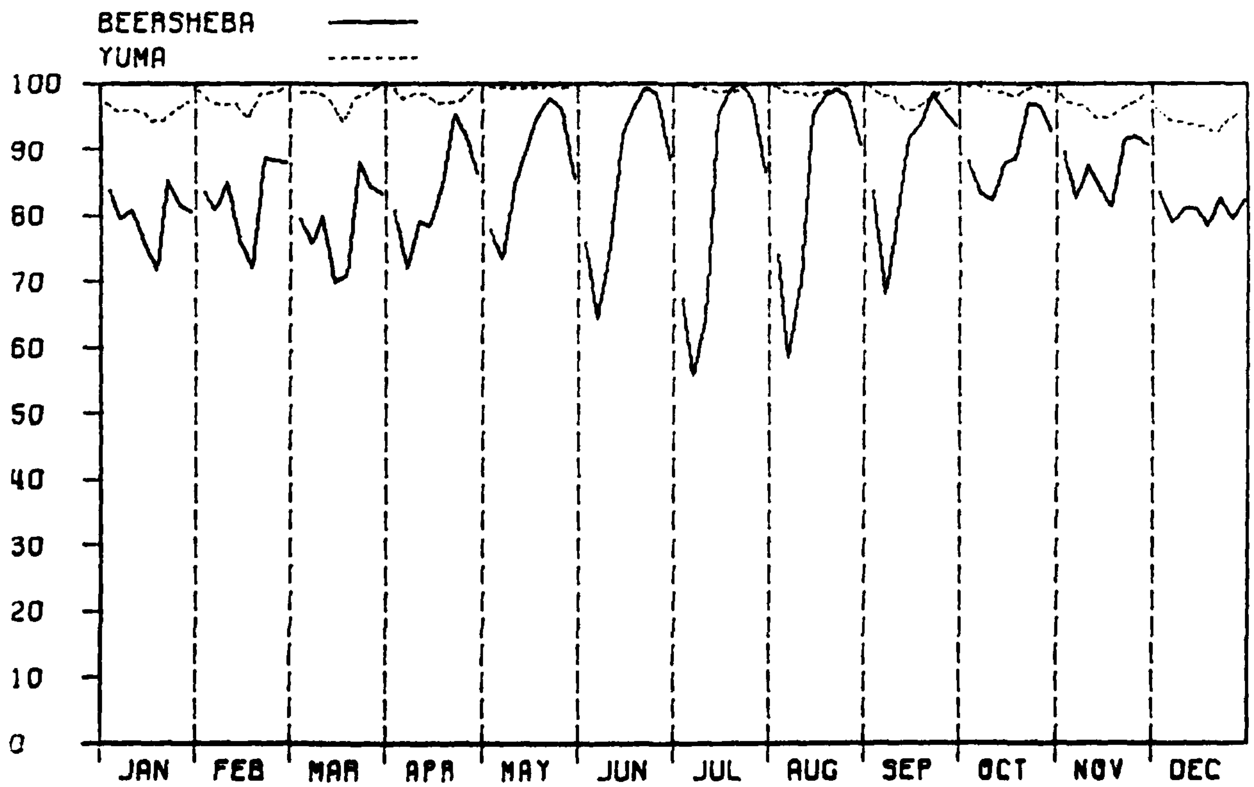
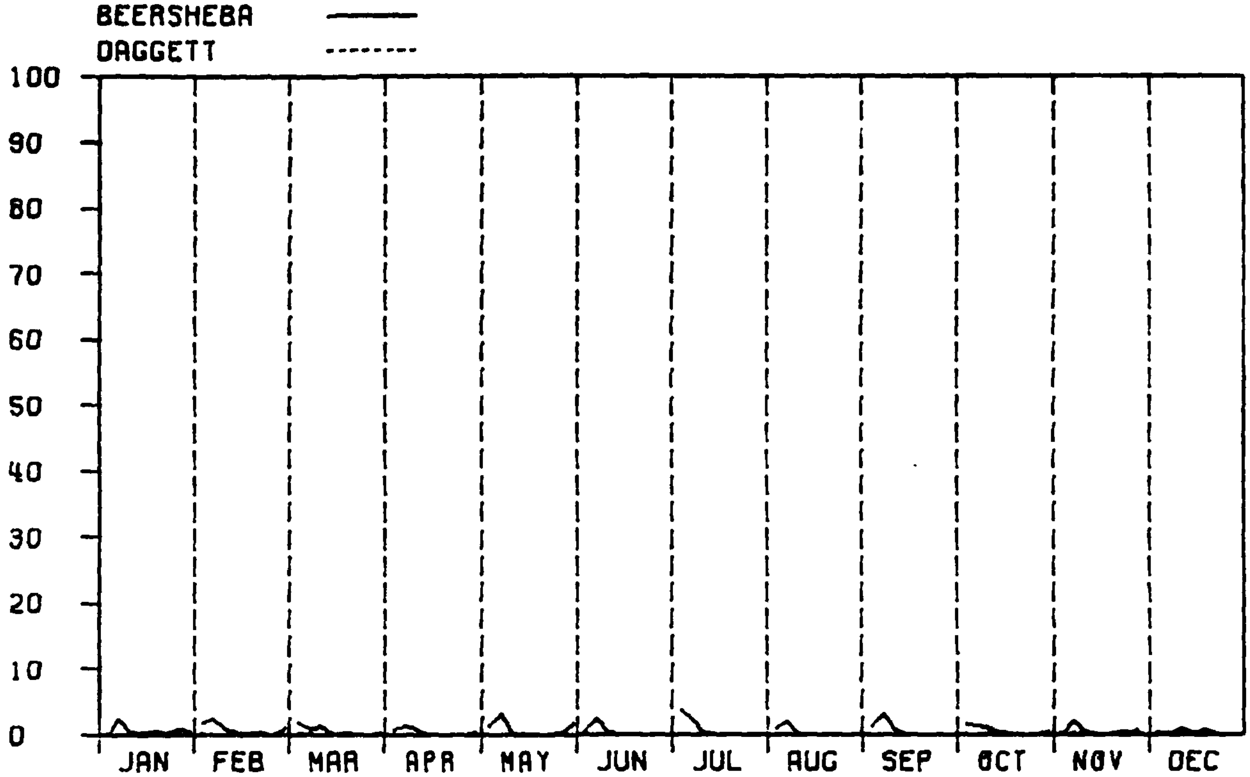



Fig. 22. (Cont'd) CEILING HEIGHT - METERS
CLASS = 50 - 199
FREQUENCY (IN PER CENT). BY 3-HOURLY PERIOD AND BY MONTH



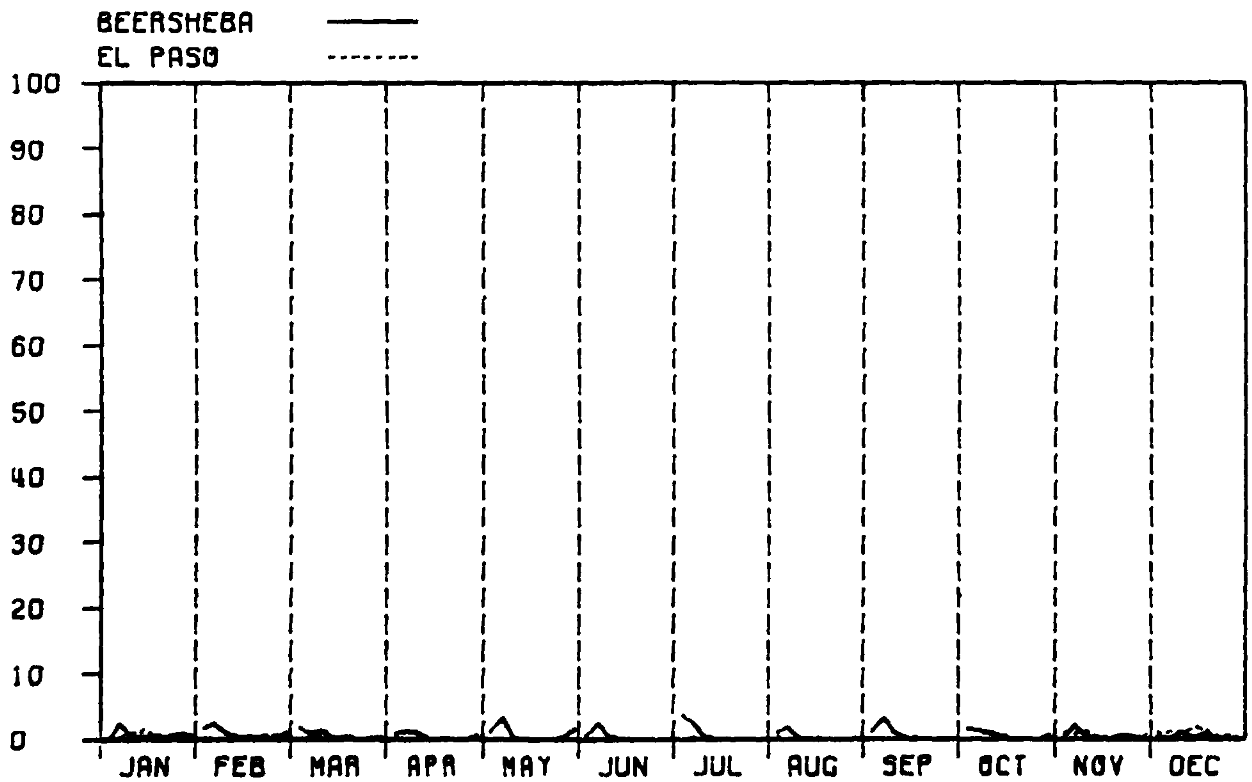
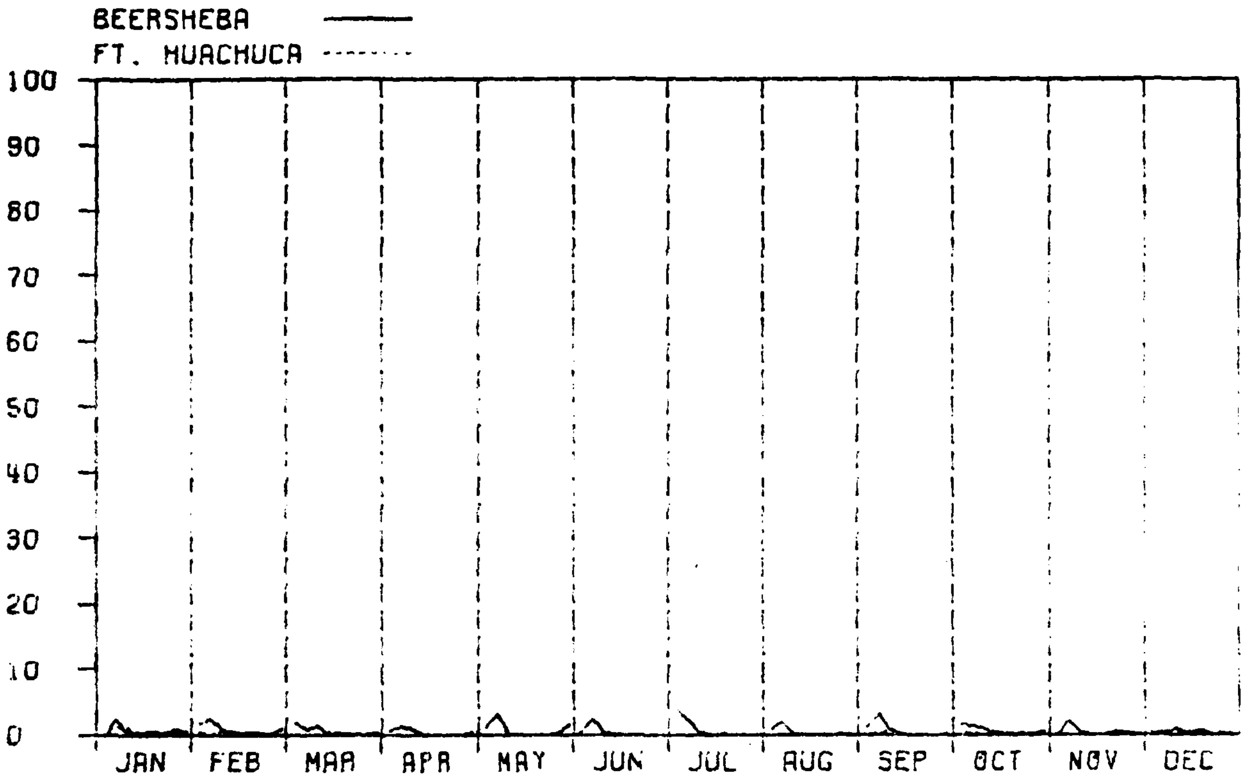



Fig. 22. (Cont'd) CEILING HEIGHT - METERS
CLASS = 50 - 199
FREQUENCY (IN PER CENT). BY 3-HOURLY PERIOD AND BY MONTH



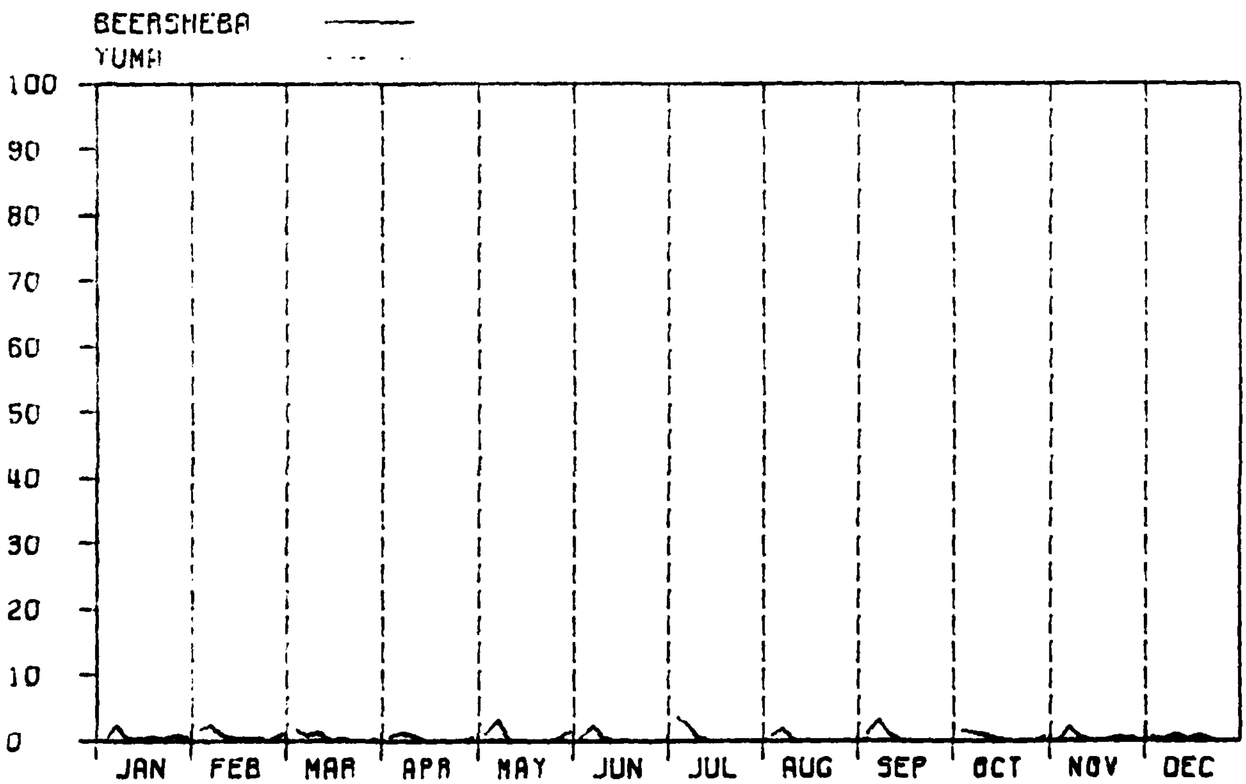
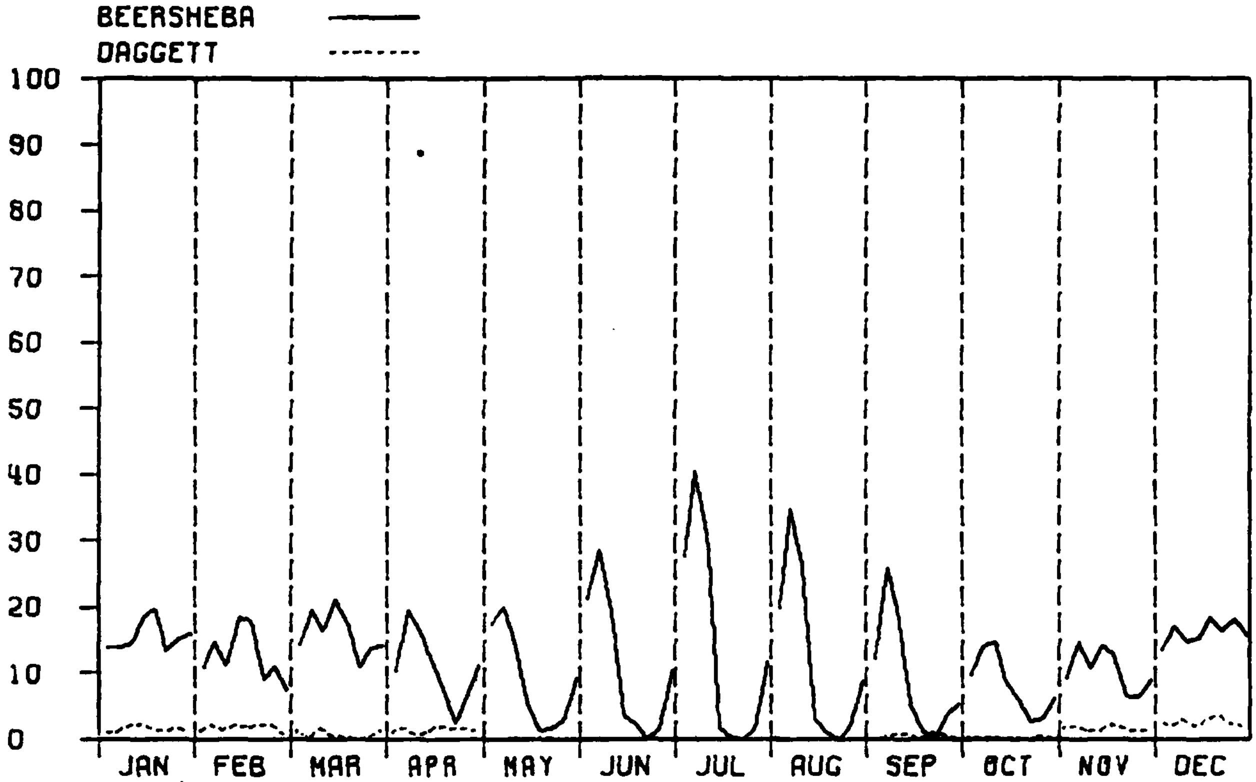



Fig. 22. (Cont'd) CEILING HEIGHT - METERS
CLASS = 200 - 999
FREQUENCY (IN PER CENT). BY 3-HOURLY PERIOD AND BY MONTH



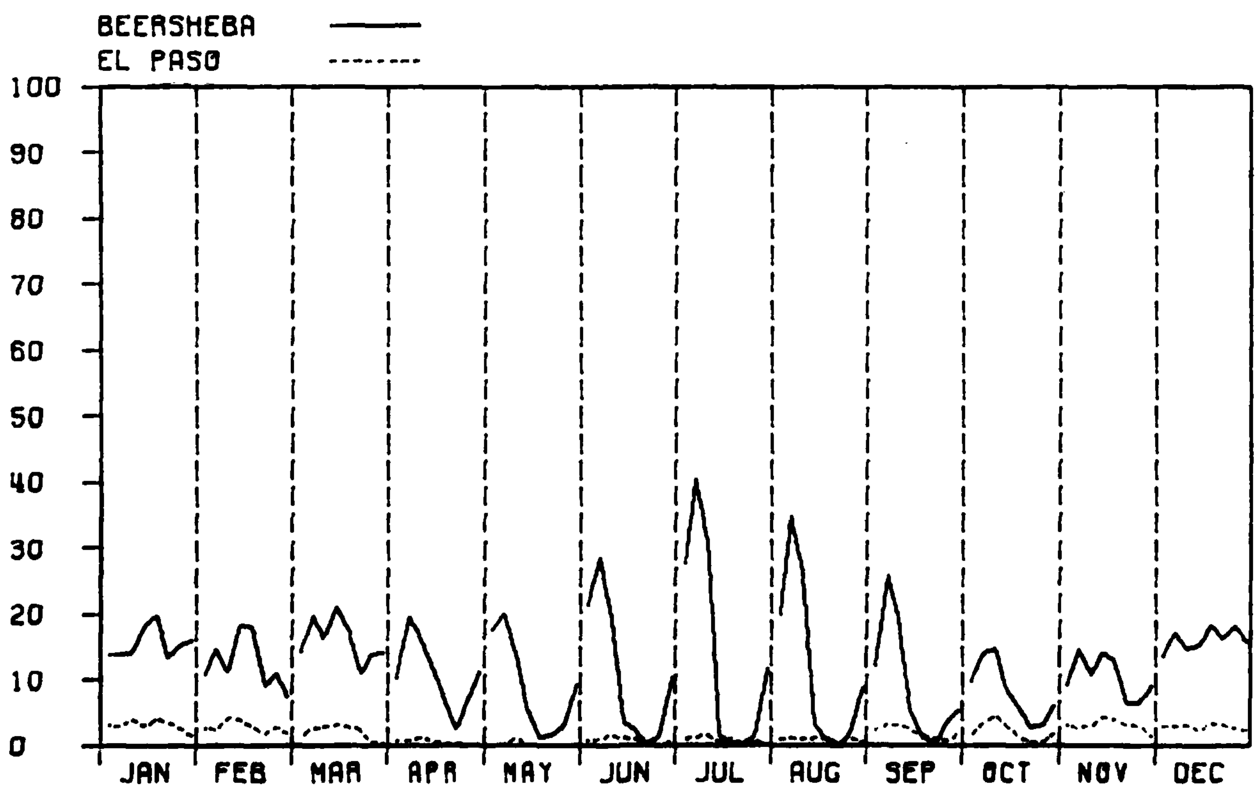
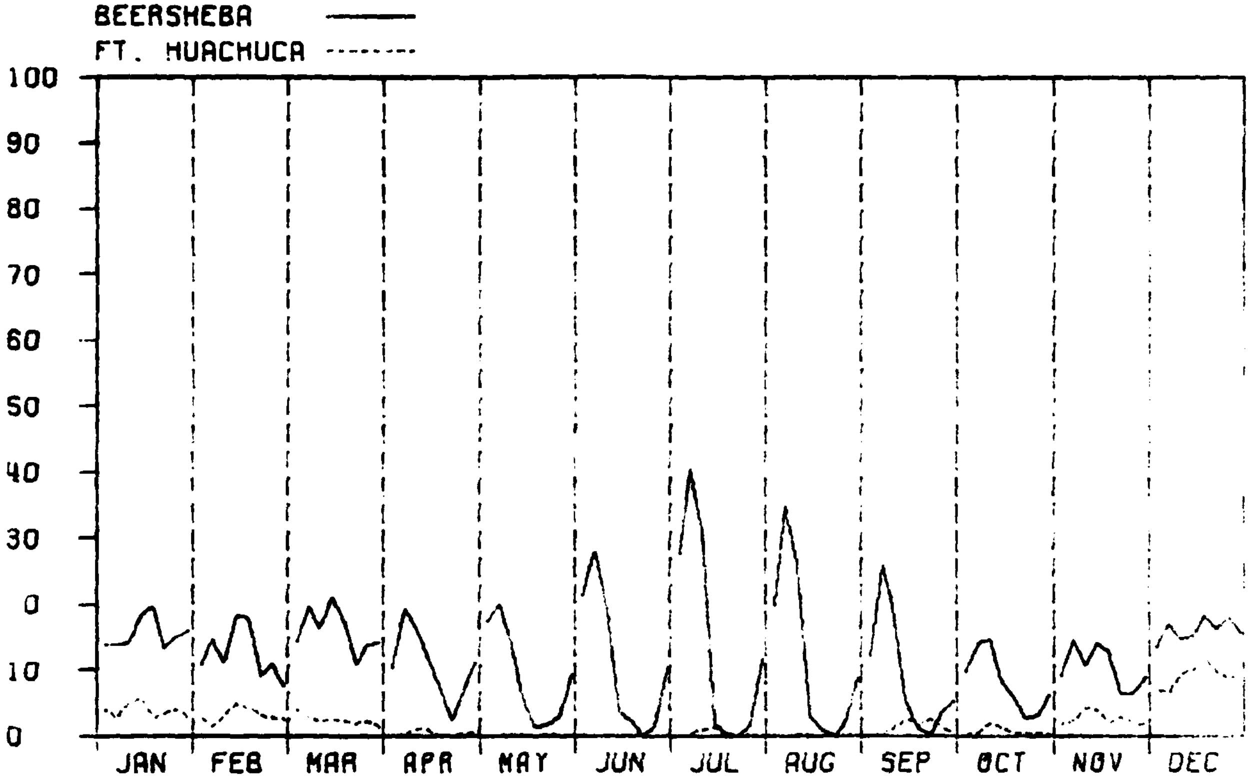



Fig. 22. (Cont'd) CEILING HEIGHT - METERS
CLASS = 200 - 999
FREQUENCY (IN PER CENT). BY 3-HOURLY PERIOD AND BY MONTH



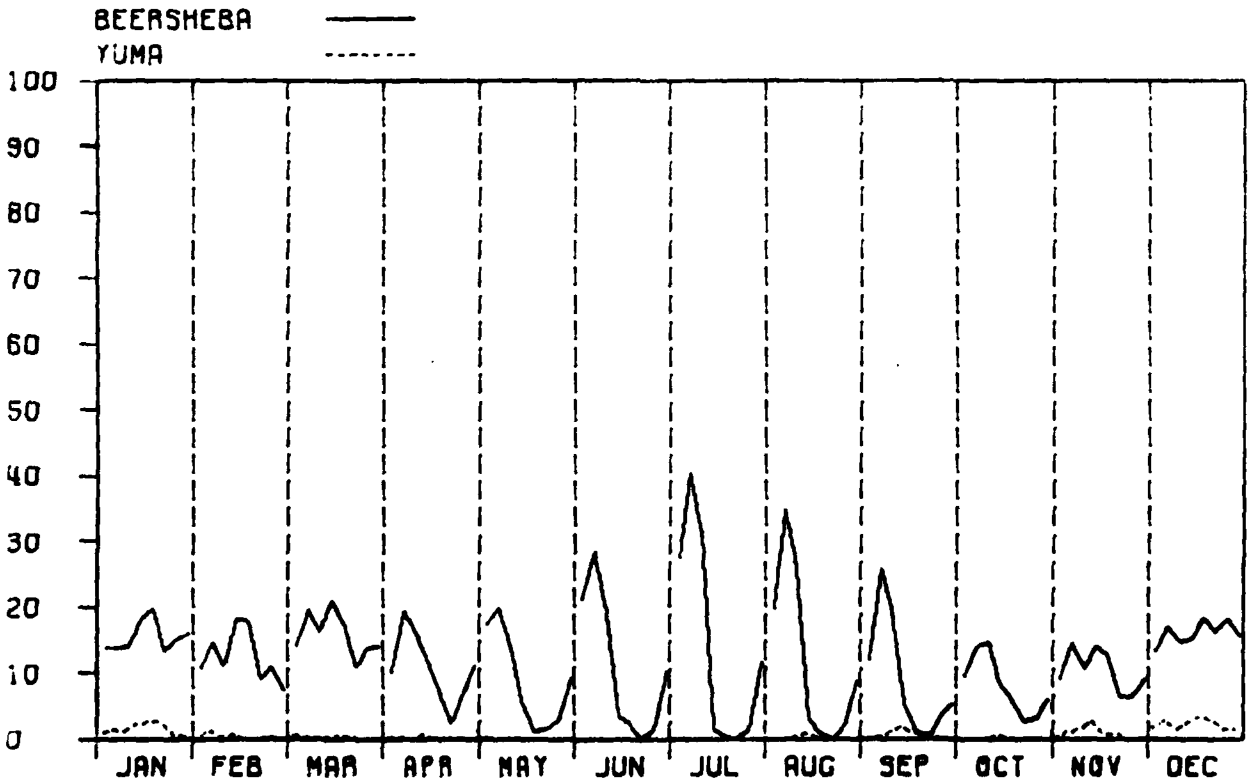
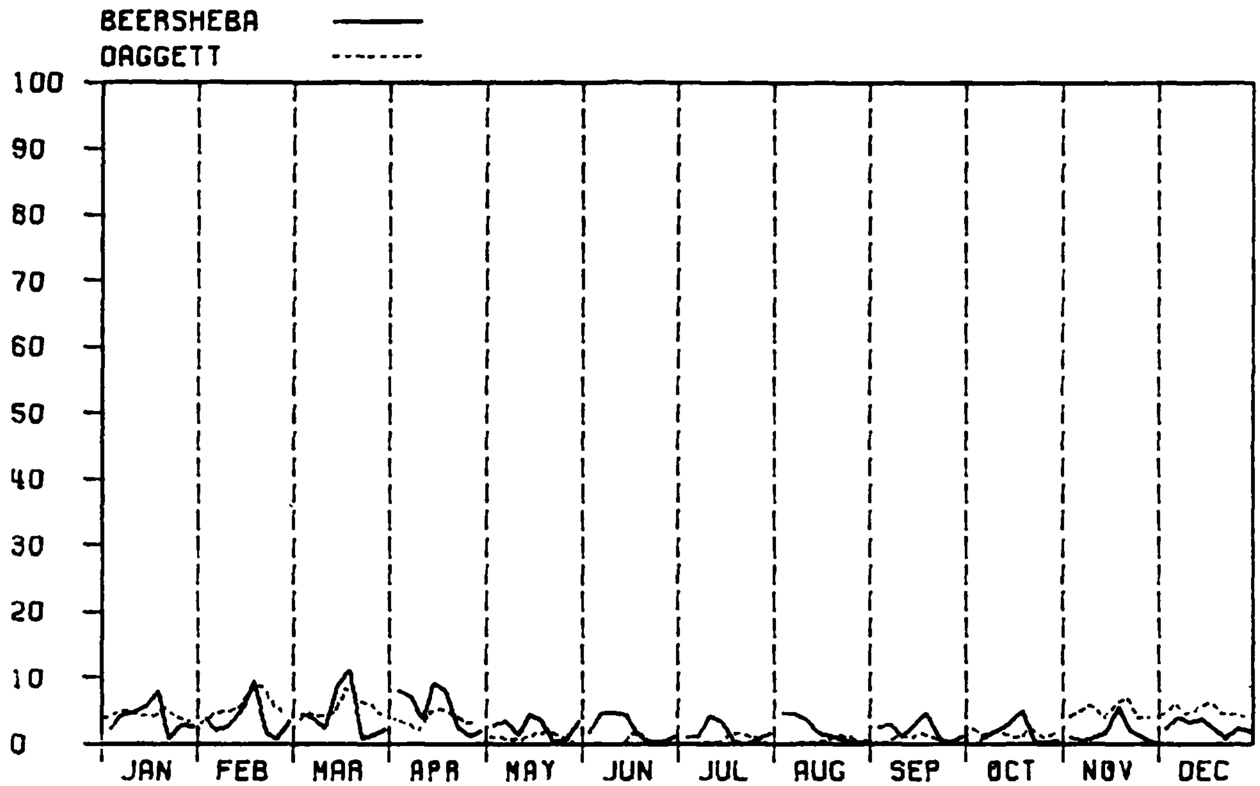



Fig. 22. (Cont'd) CEILING HEIGHT - METERS
CLASS = 1000 - 1999
FREQUENCY (IN PER CENT) . BY 3-HOURLY PERIOD AND BY MONTH



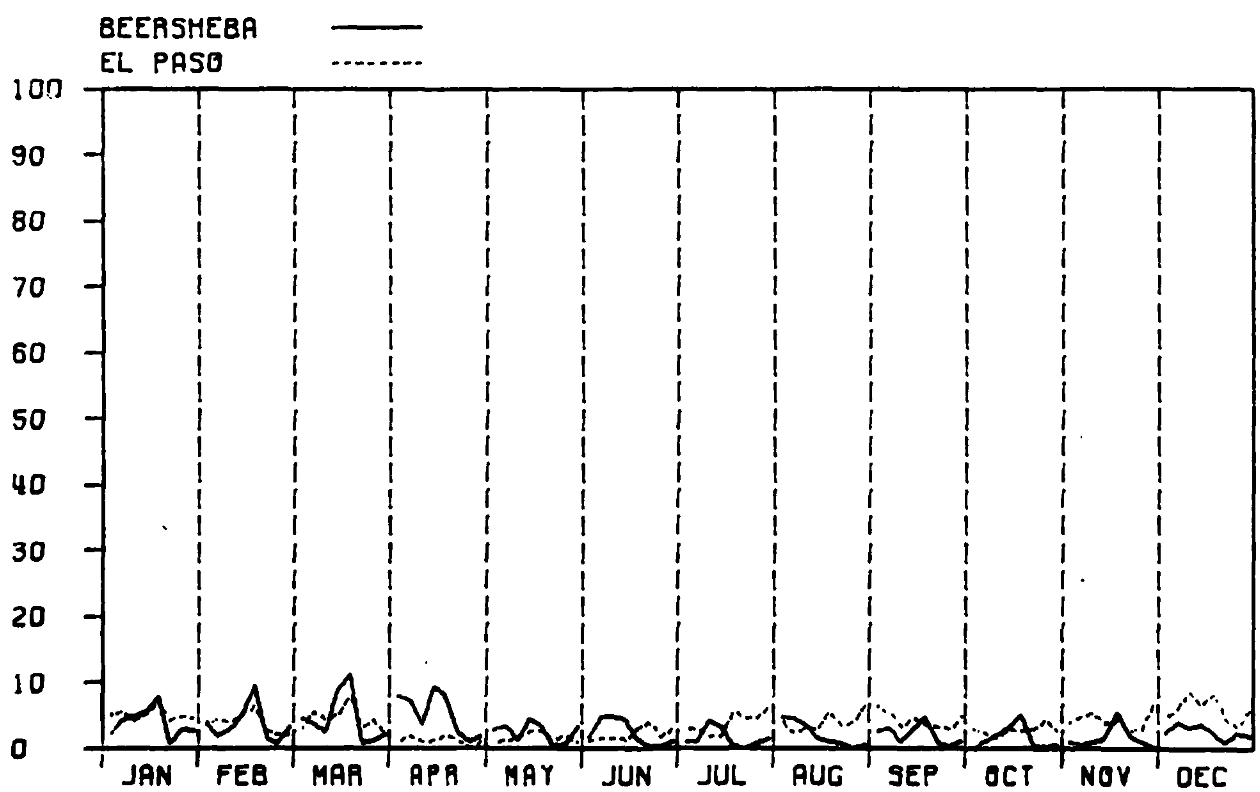
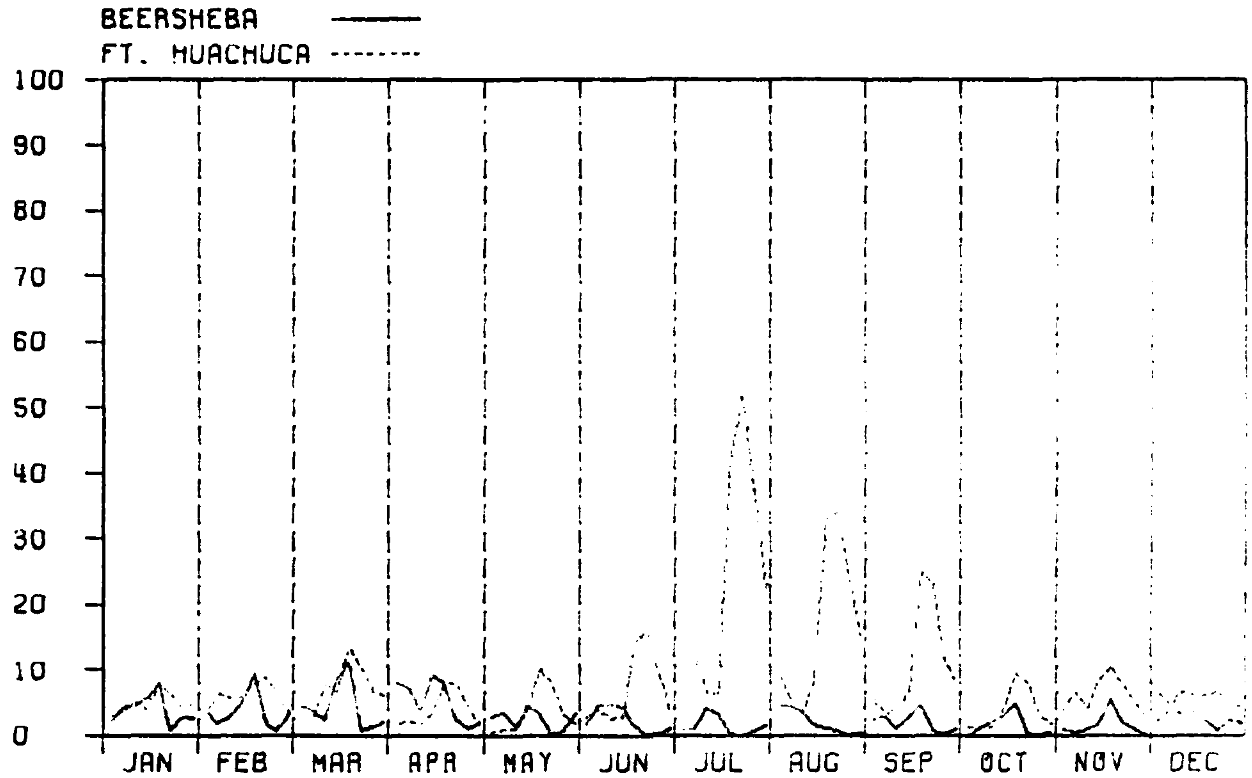



Fig. 22. (Cont'd) CEILING HEIGHT - METERS
CLASS = 1000 - 1999
FREQUENCY (IN PER CENT). BY 3-HOURLY PERIOD AND BY MONTH



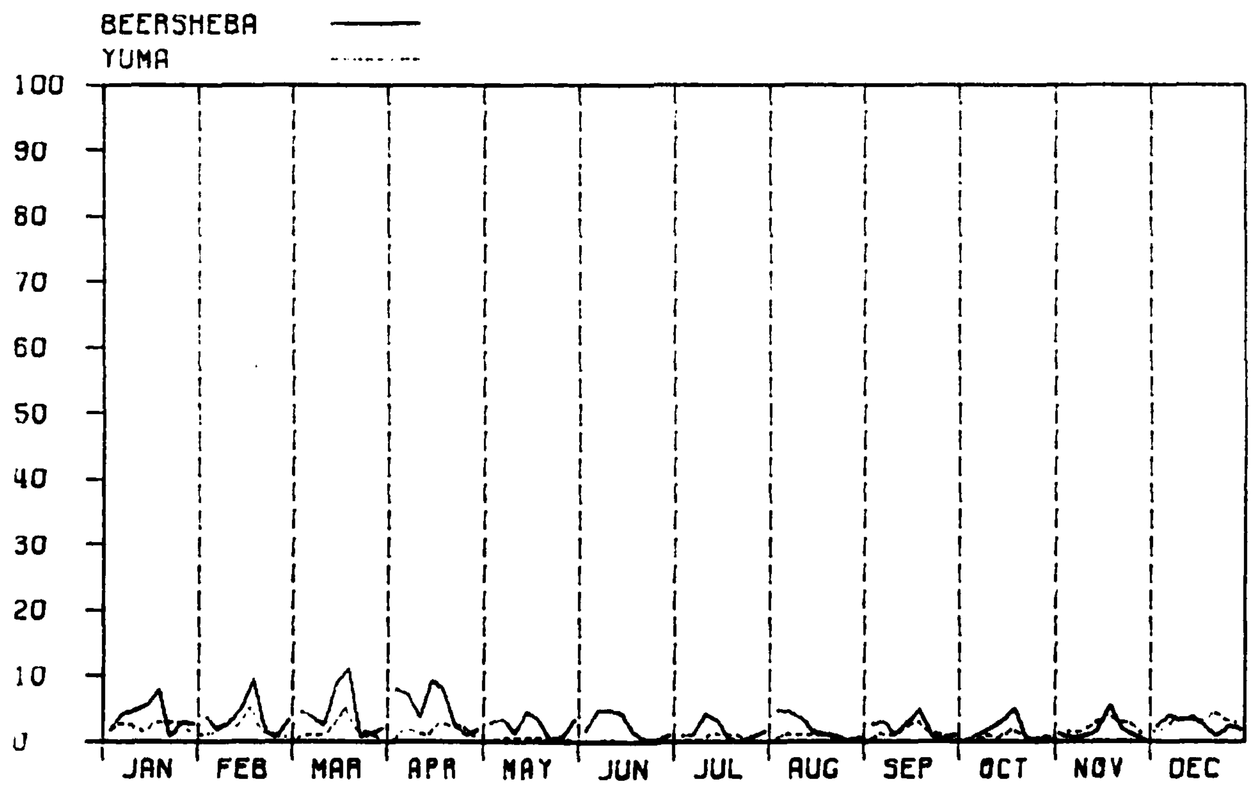



Fig. 23. CEILING HEIGHT - METERS
CLASS = 0 - 49
FREQUENCY (IN PER CENT), BY MONTH

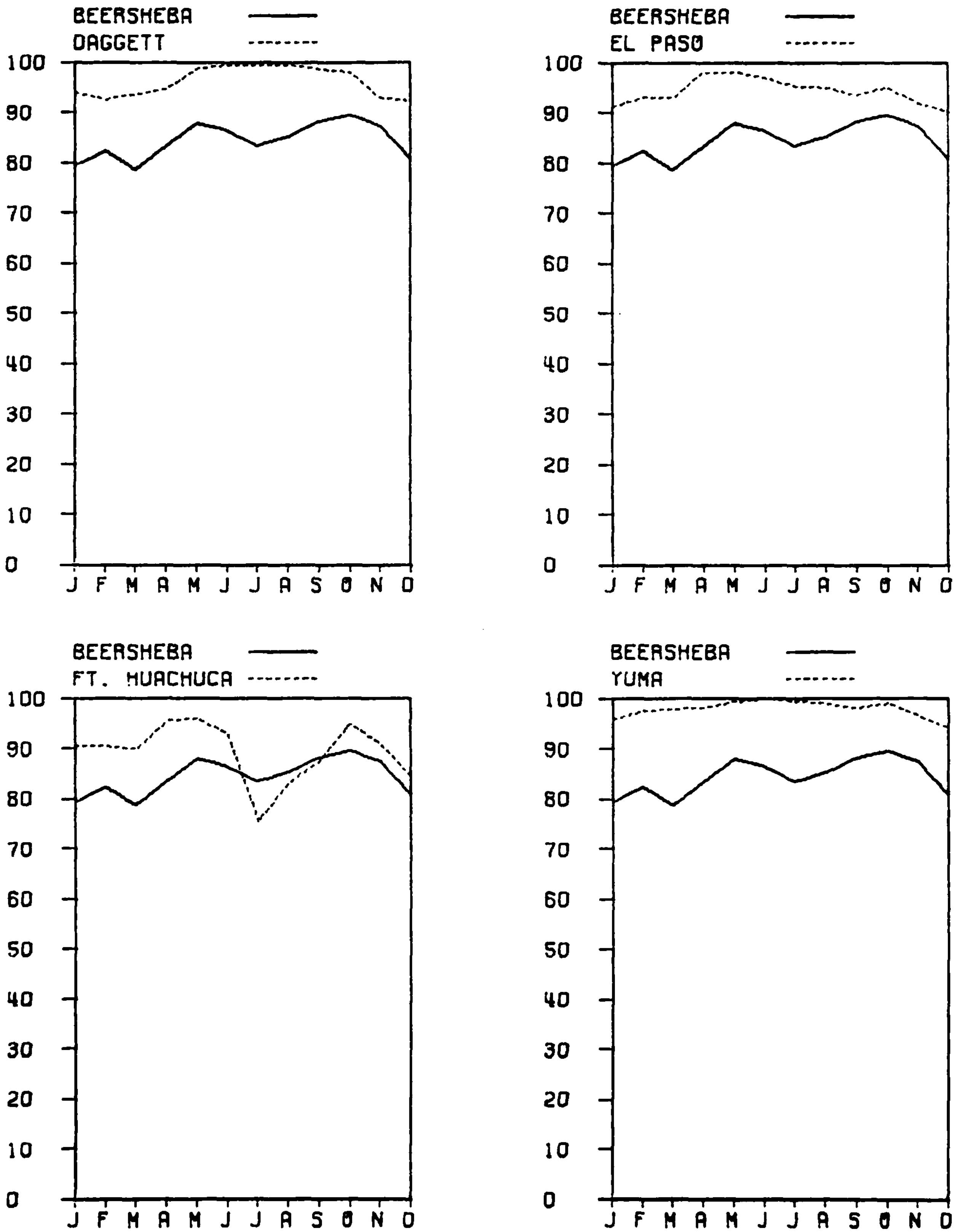


Fig. 23. (Cont'd) CEILING HEIGHT - METERS
CLASS = 50 - 199
FREQUENCY (IN PER CENT), BY MONTH

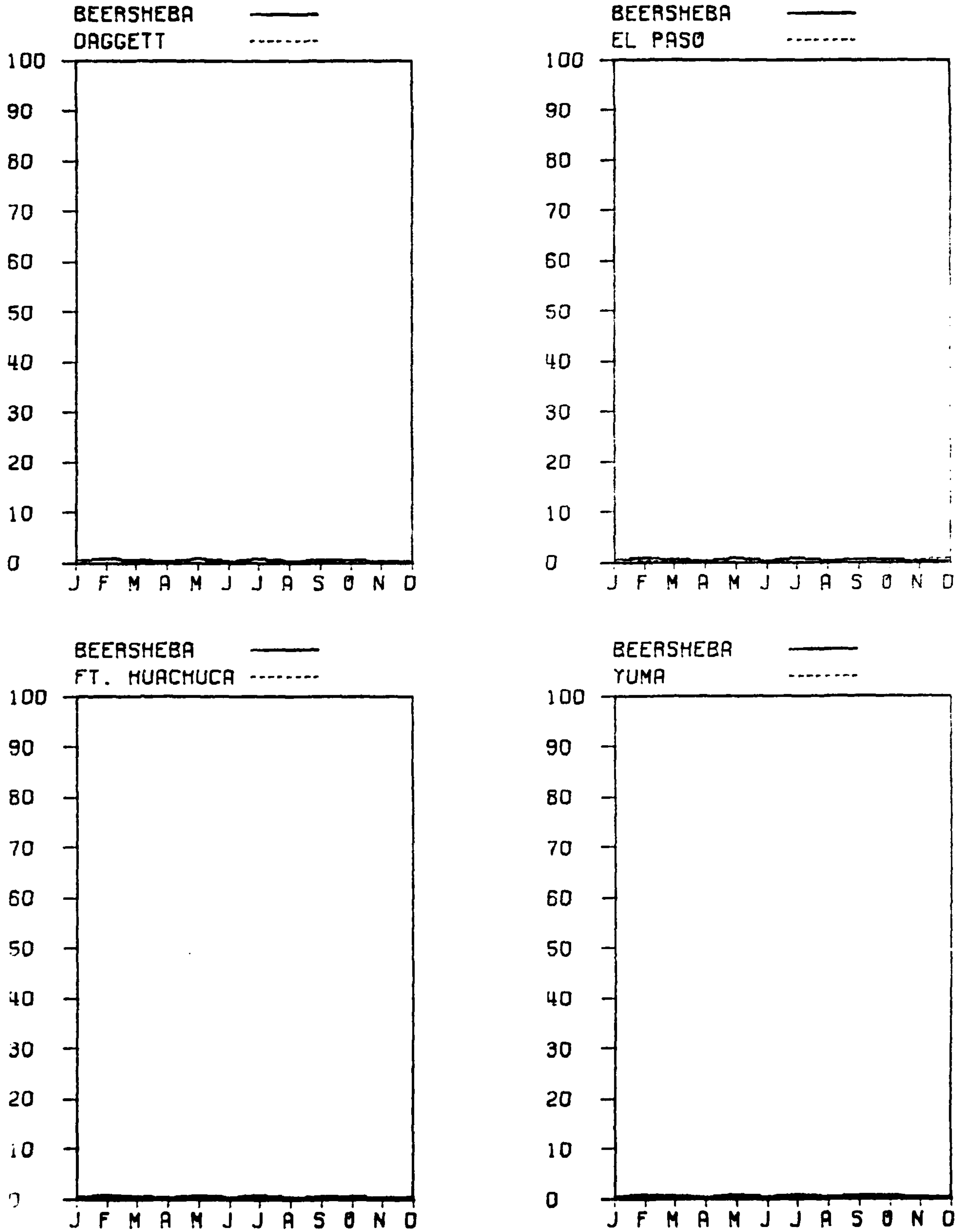


Fig. 23. (Cont'd) CEILING HEIGHT - METERS
CLASS = 200 - 999
FREQUENCY (IN PER CENT), BY MONTH

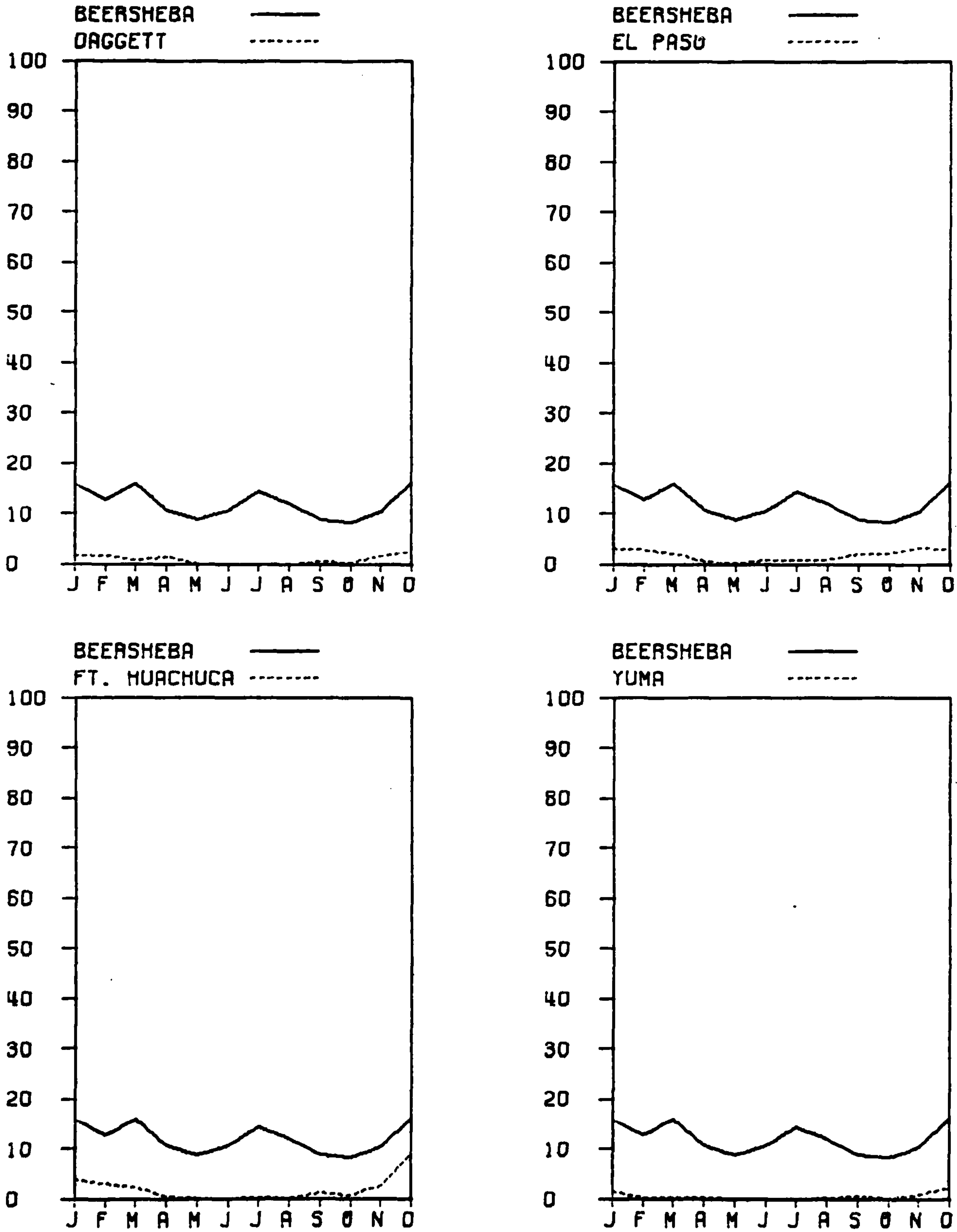
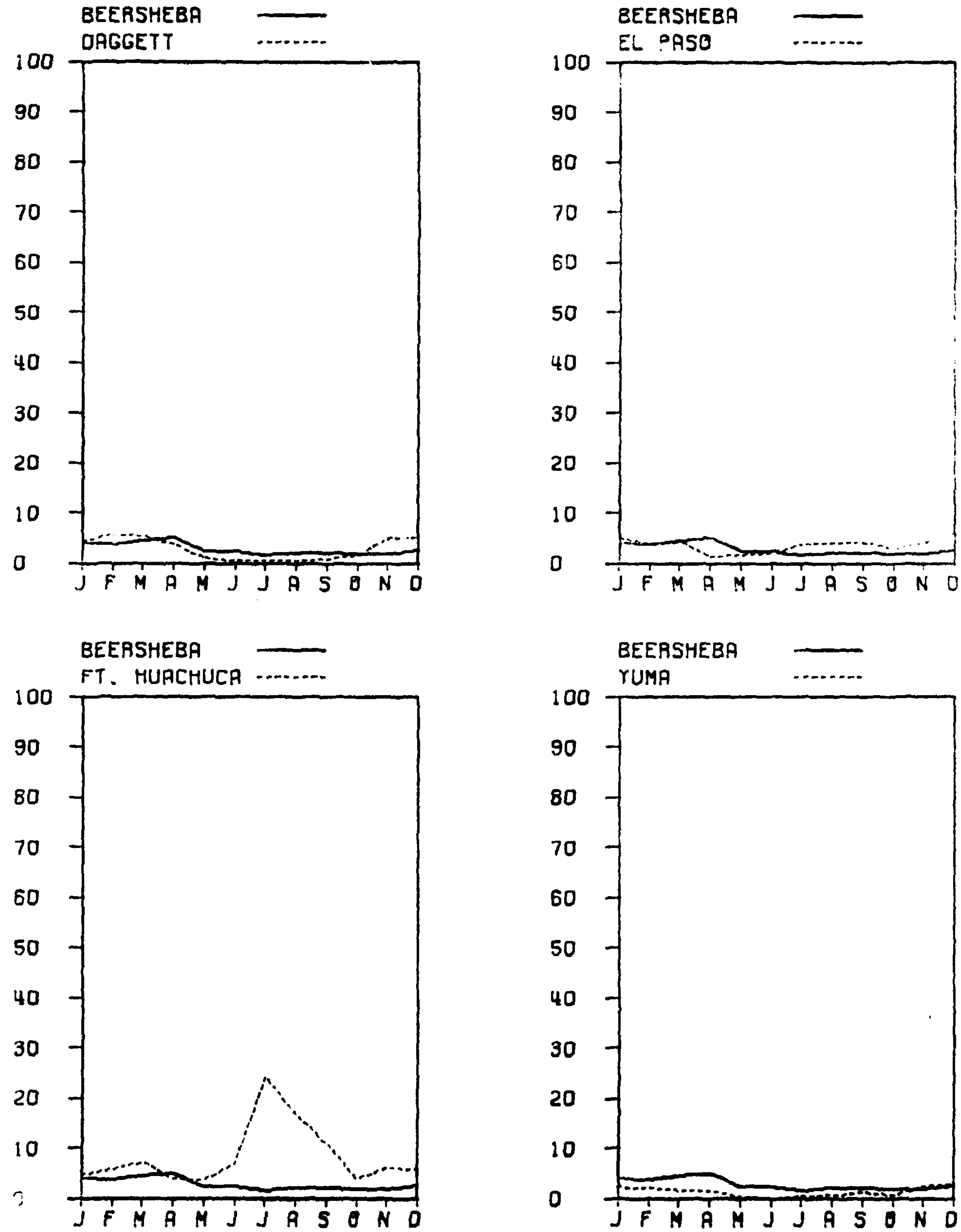


Fig. 23. (Cont'd) CEILING HEIGHT - METERS
CLASS = 1000 - 1999
FREQUENCY (IN PER CENT), BY MONTH



## D. Wind Direction

On the Beersheba data tape the wind direction is given to the nearest whole degree; on the U.S. data tapes it is given in tens of degrees starting with north. Each wind direction was placed into one of five classes: calm, north ($315° < dir \leq 45°$), east ($45° < dir \leq 135°$), south ($135° < dir \leq 225°$), west ($225° < dir \leq 315°$).

The 3-hourly frequencies by month for the five classes are presented in Fig. 24. Except for Daggett the evening hours are the time of maximum occurrence of calm wind and the afternoon hours the time of minimum occurrence, as would be expected. During the summer months at Daggett the evening hours are the time of minimum frequency of calm wind and the afternoon hours the time of maximum frequency. The reason is not apparent. The maximum at Ft. Huachuca is at 0800 hr every month of the year. Beersheba has the highest frequency of calm wind among the five stations and this occurs in the early morning hours (~0200 hr).

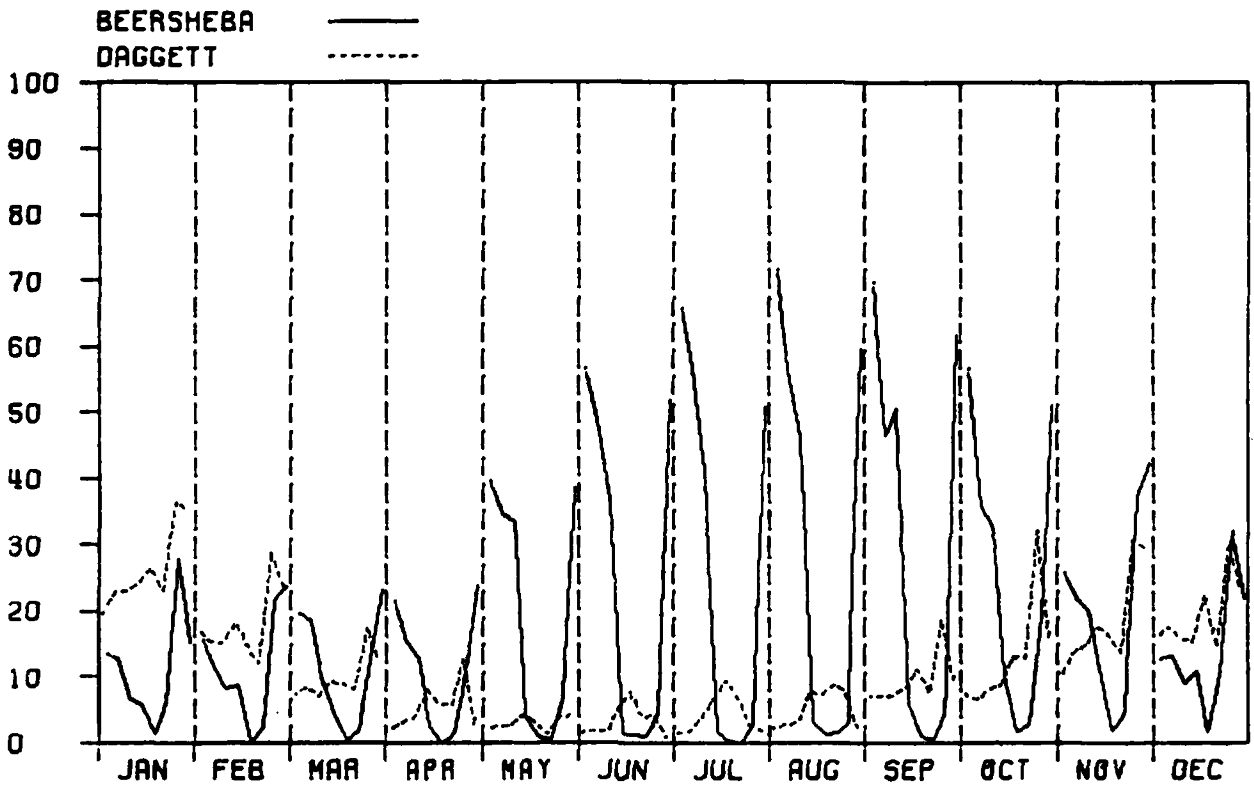
The remaining 3-hourly plots for the cardinal points of the compass show that each station tends to have a diurnal variation for each direction. This implies that there is, on the average, some systematic change in wind direction throughout the course of a day, which can change from month to month.

Fig. 25 shows that the maximum frequency of calm wind at Daggett, El Paso and Ft. Huachuca occurs in winter while the maximum at Beersheba occurs in summer (late). The average

annual frequency of occurrence of calm wind varies from 10 to 15% among the U.S. stations and is about 18% at Beersheba.

In looking at the remaining plots it is clear that Daggett has the most persistent wind direction. About 75% of the year the wind direction is either west or calm. The dominant Beersheba wind directions tend to be north and west (65%) during the summer months and east and west (65%) during the winter months. The south and east directions are most common (60%) in summer at El Paso, south and west (60%) in the spring months, and all directions are roughly equally likely during the remainder of the year. At Ft. Huachuca north is the least likely direction (8% annually), south and west the most likely directions (70%) in the spring and early summer months. The most common wind direction in winter at Yuma is north (50%), the most common in summer is south (55%), and east the least common year round (~10%).

Fig. 24. WIND DIRECTION
CLASS = CALM
FREQUENCY (IN PER CENT). BY 3-HOURLY PERIOD AND BY MONTH



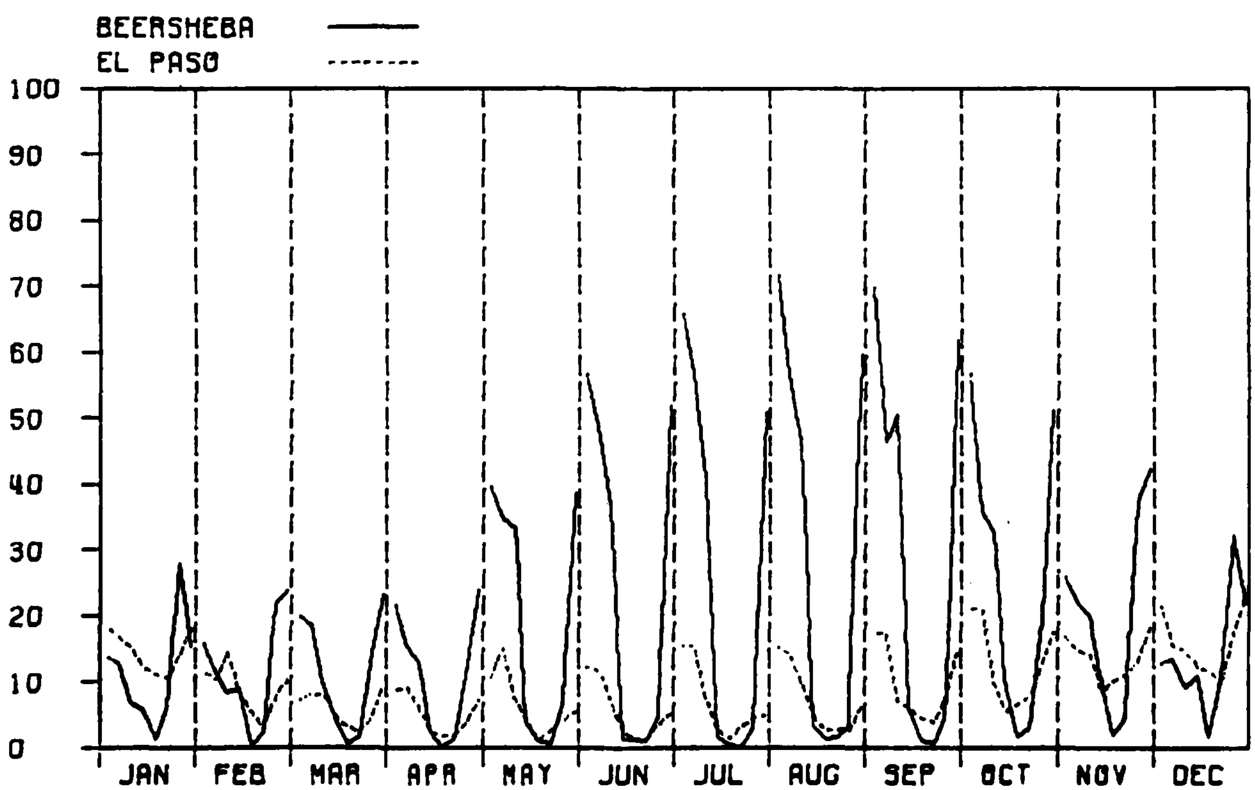
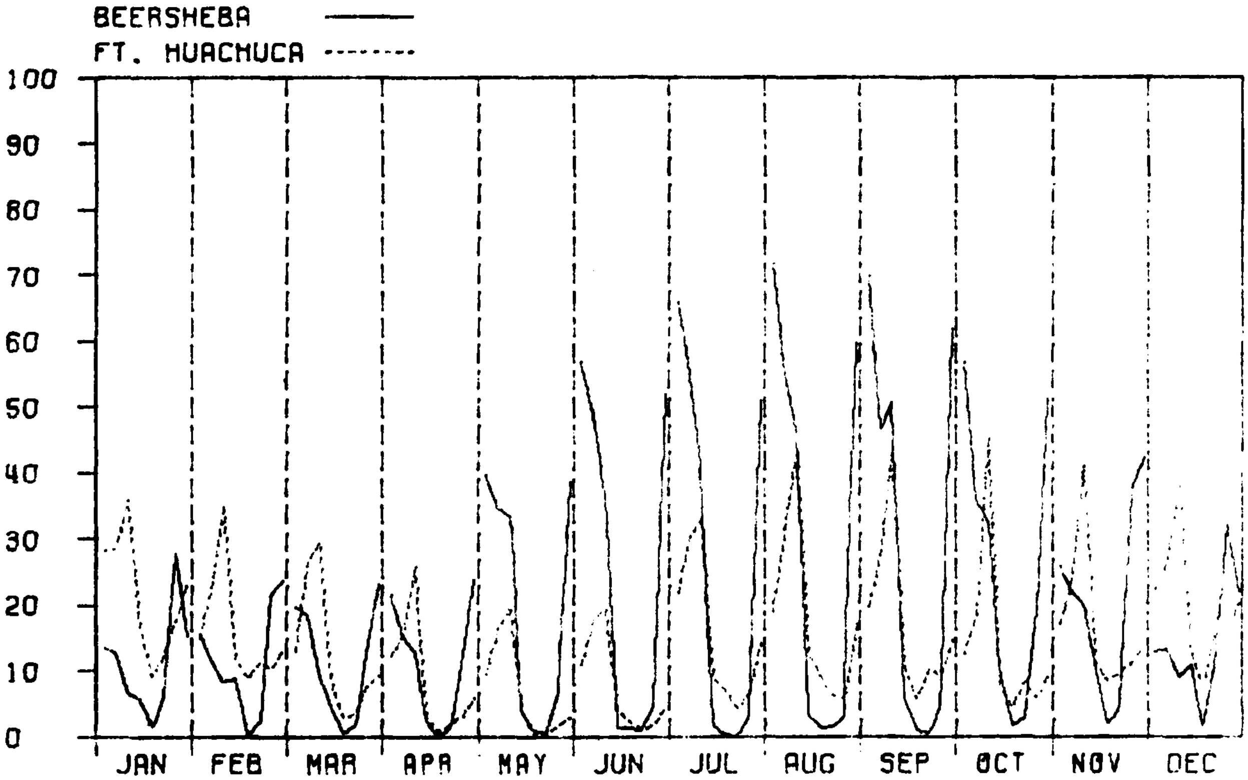



Fig. 24. (Cont'd) WIND DIRECTION

CLASS = CALM

FREQUENCY (IN PER CENT), BY 3-HOURLY PERIOD AND BY MONTH



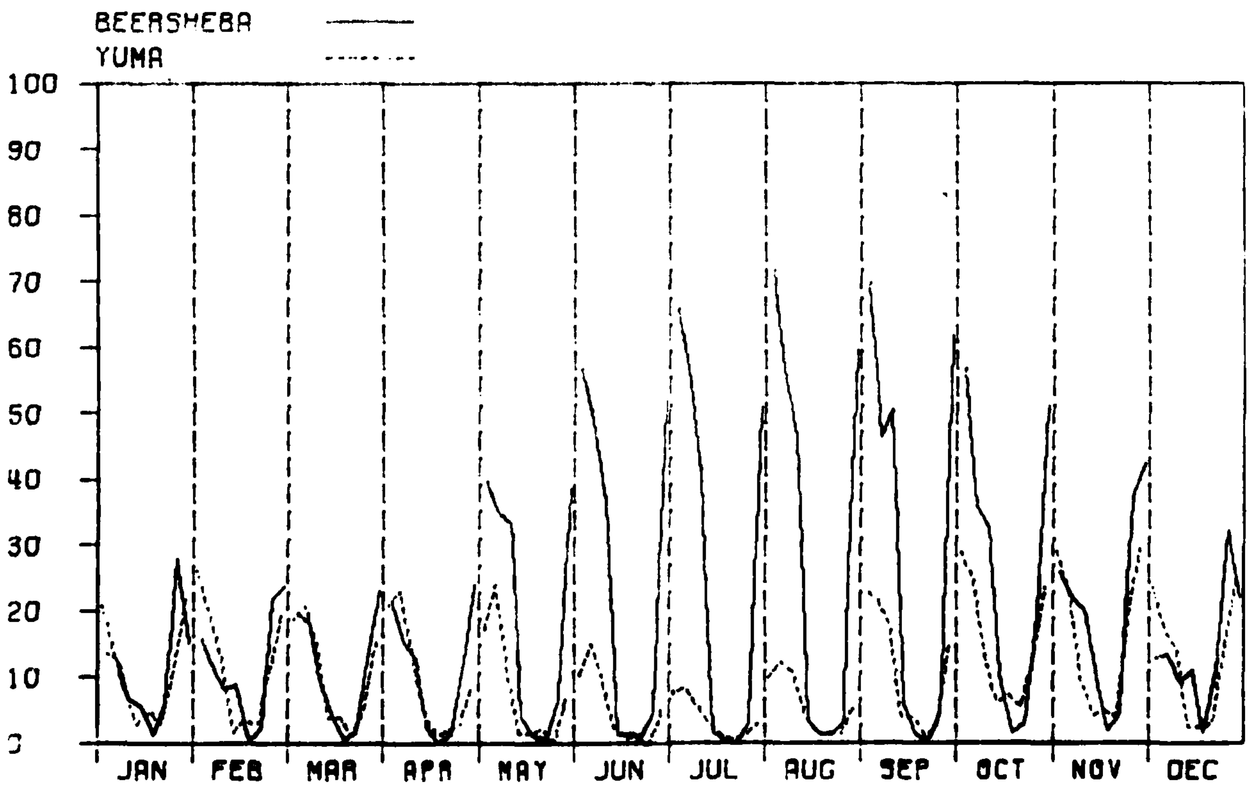
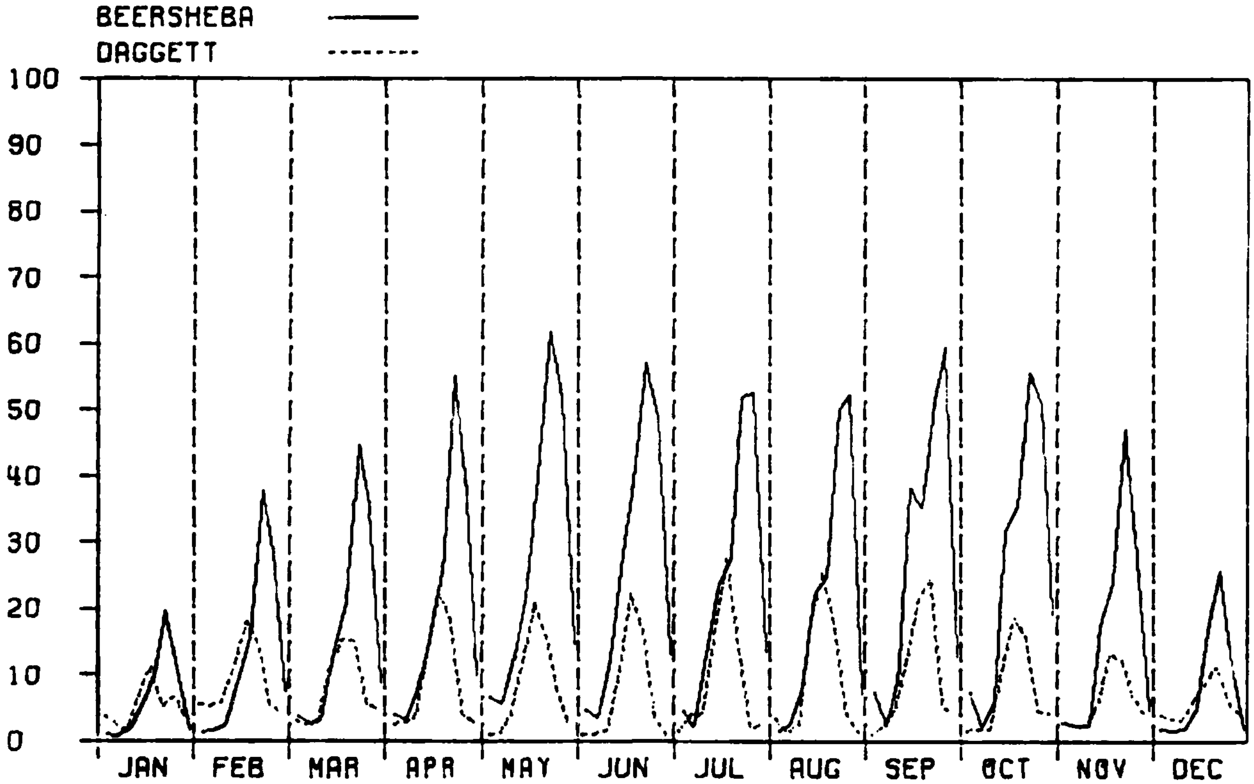



Fig. 24. (Cont'd) WIND DIRECTION
CLASS = NORTH
FREQUENCY (IN PER CENT). BY 3-HOURLY PERIOD AND BY MONTH



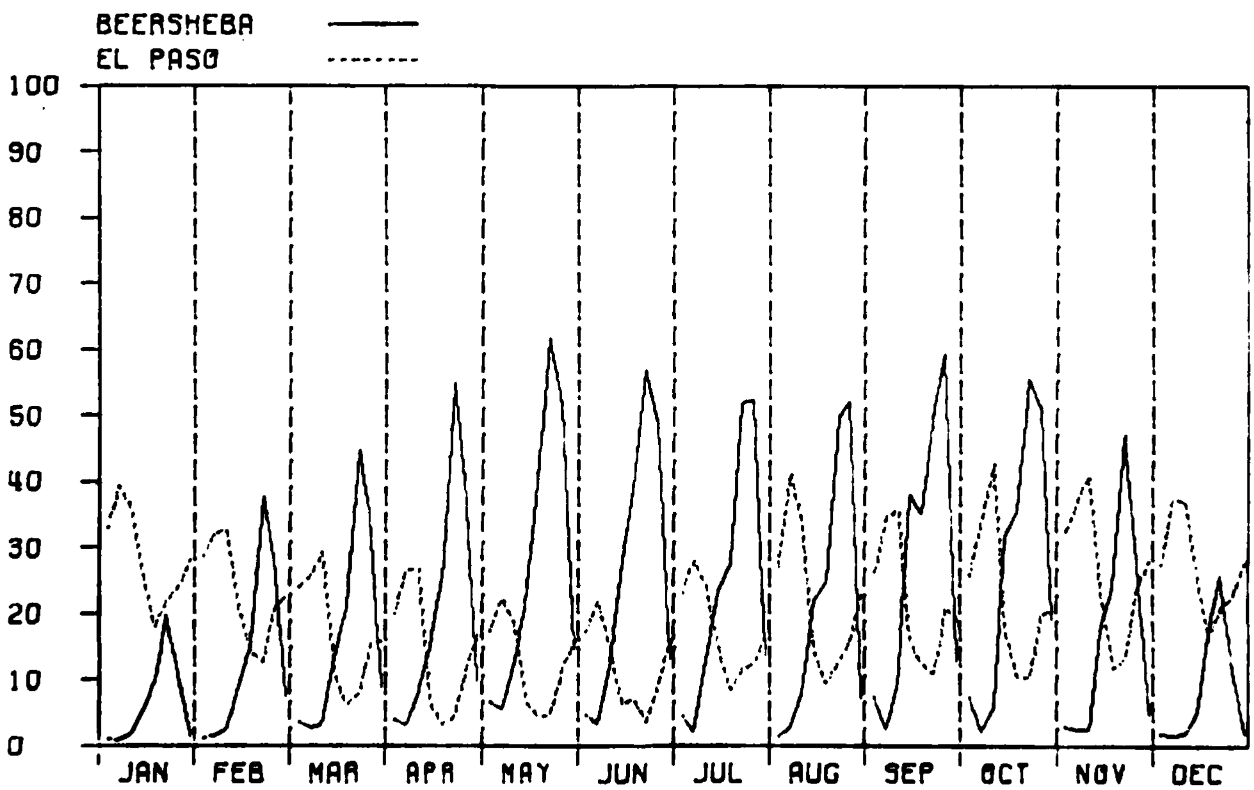
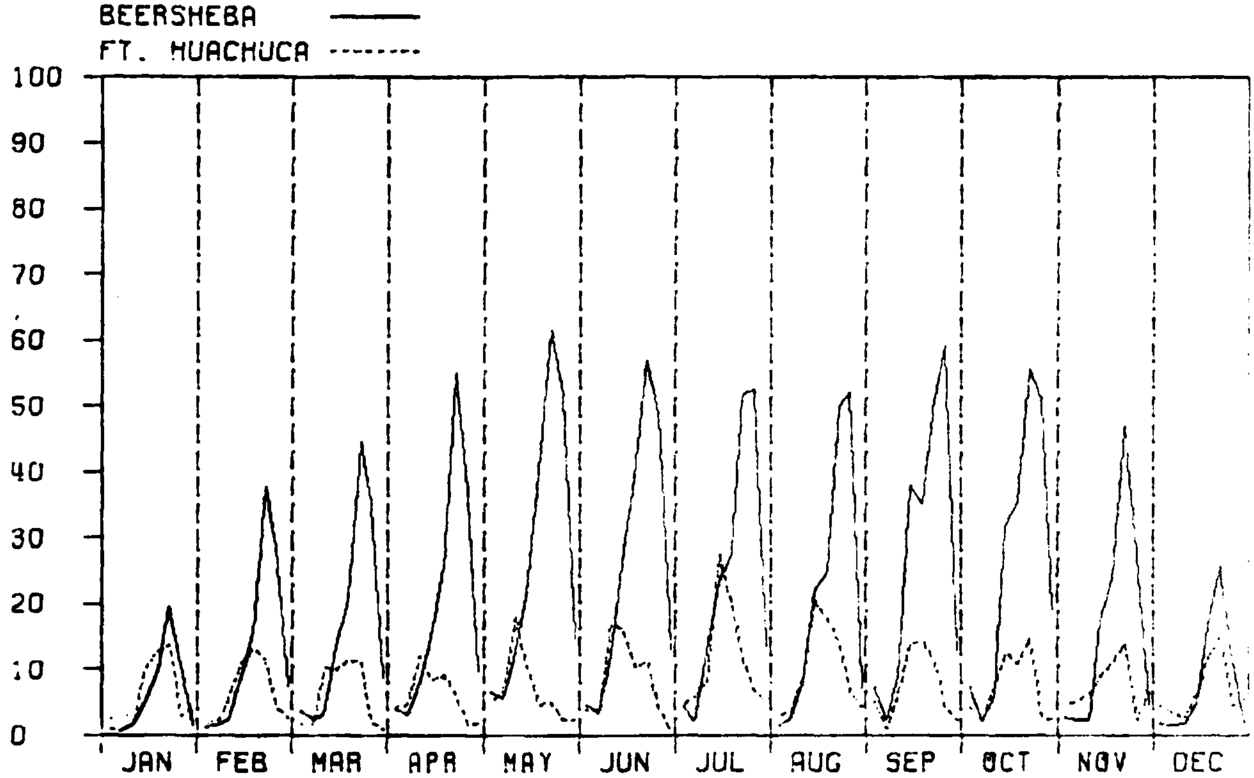



Fig. 24. (Cont'd) WIND DIRECTION
CLASS = NORTH
FREQUENCY (IN PER CENT). BY 3-HOURLY PERIOD AND BY MONTH



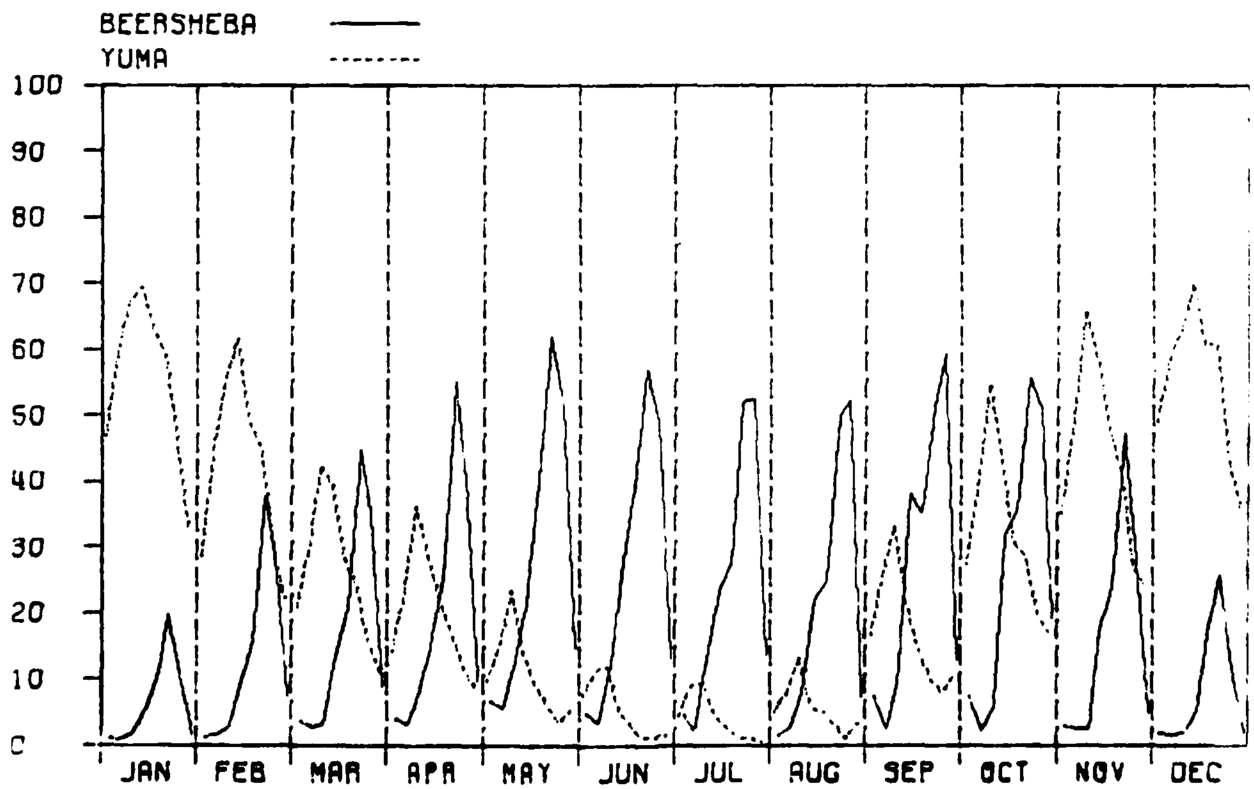
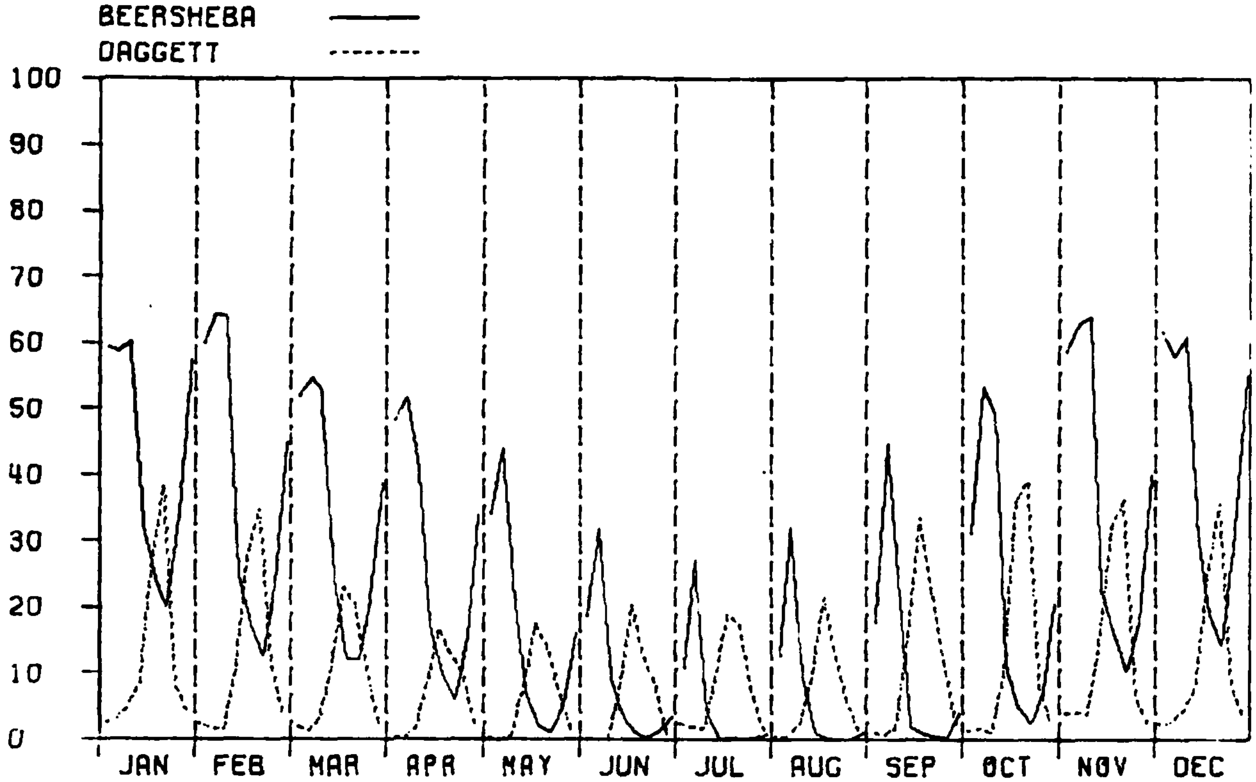



Fig. 24. (Cont'd) WIND DIRECTION
CLASS = EAST
FREQUENCY (IN PER CENT). BY 3-HOURLY PERIOD AND BY MONTH



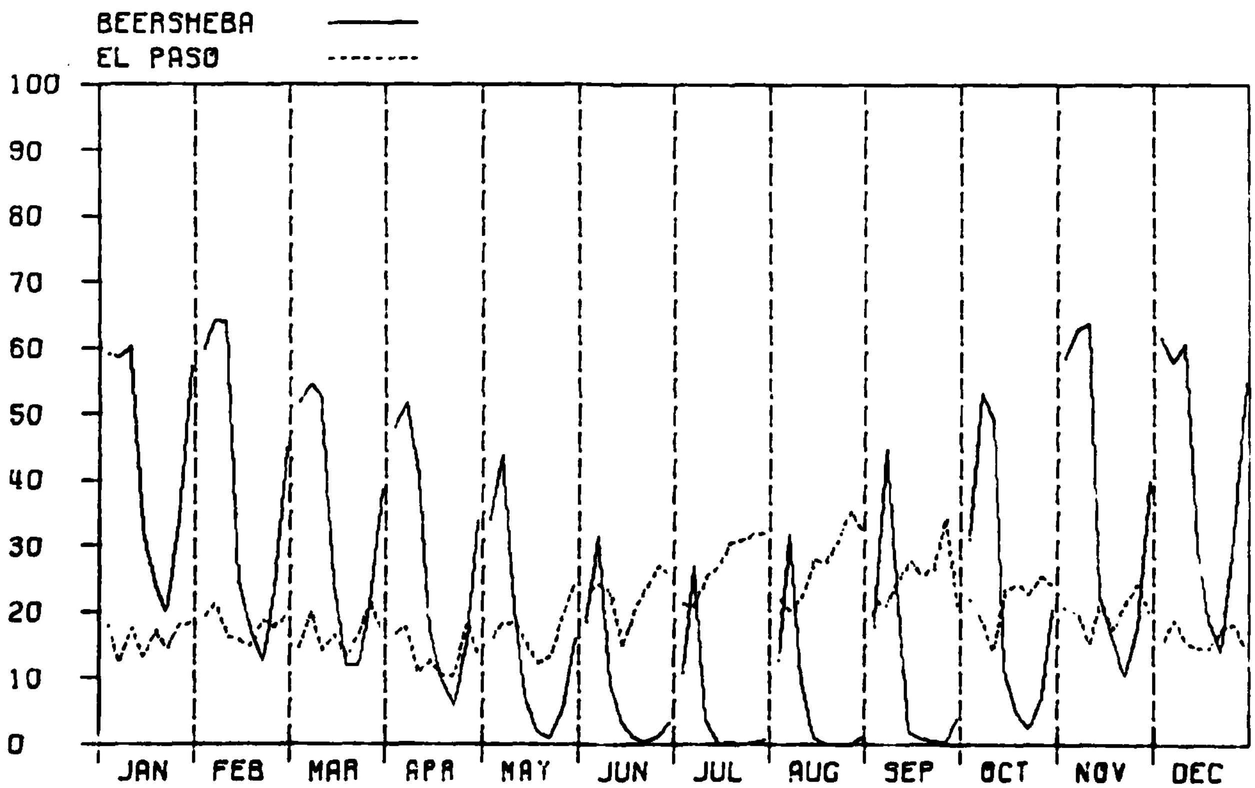
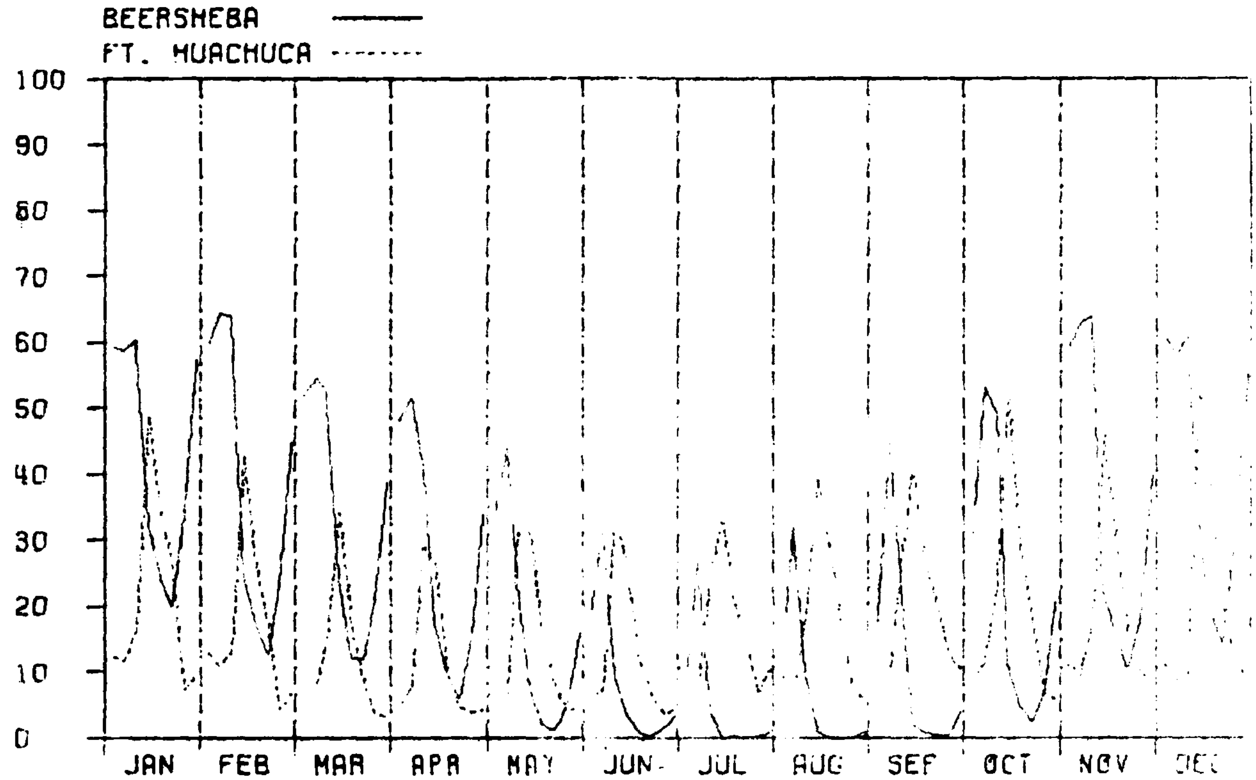



Fig. 24. (Cont'd) WIND DIRECTION

CLASS = EAST

FREQUENCY (IN PER CENT). BY 3-HOURLY PERIOD AND BY MONTH



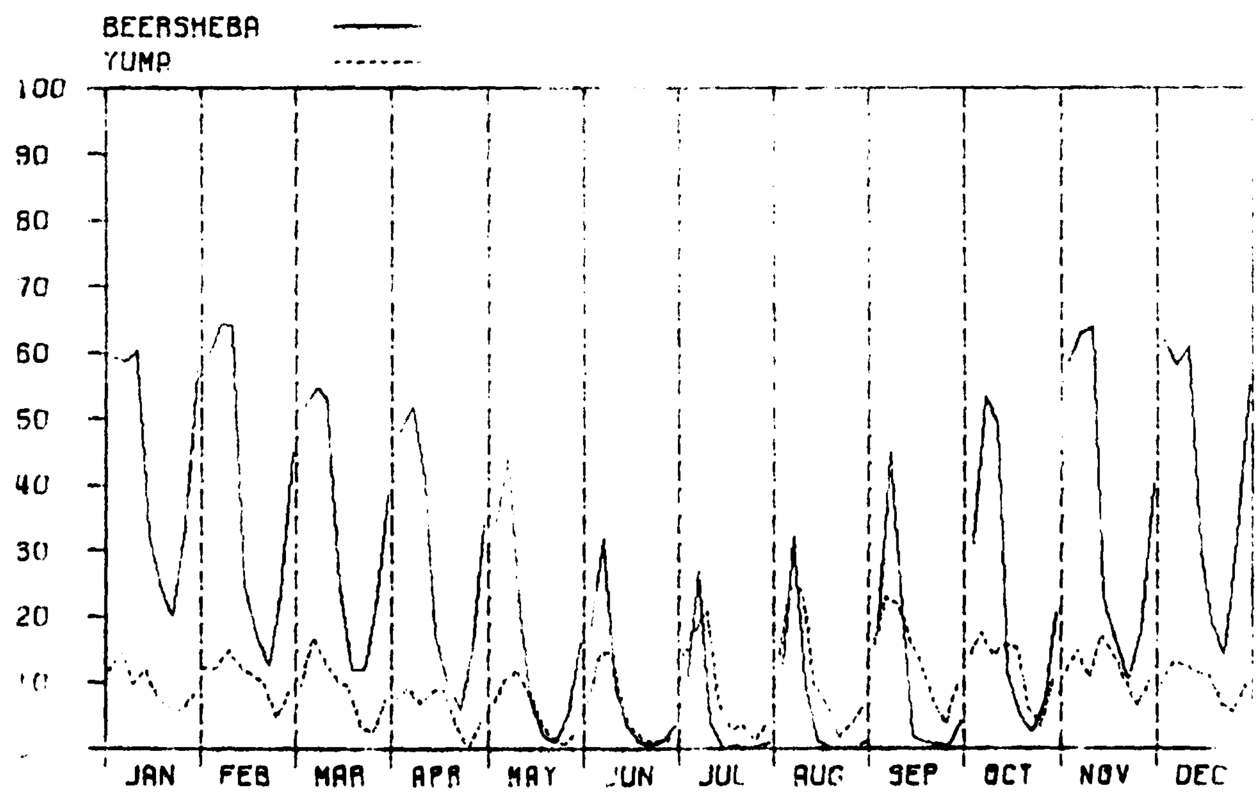
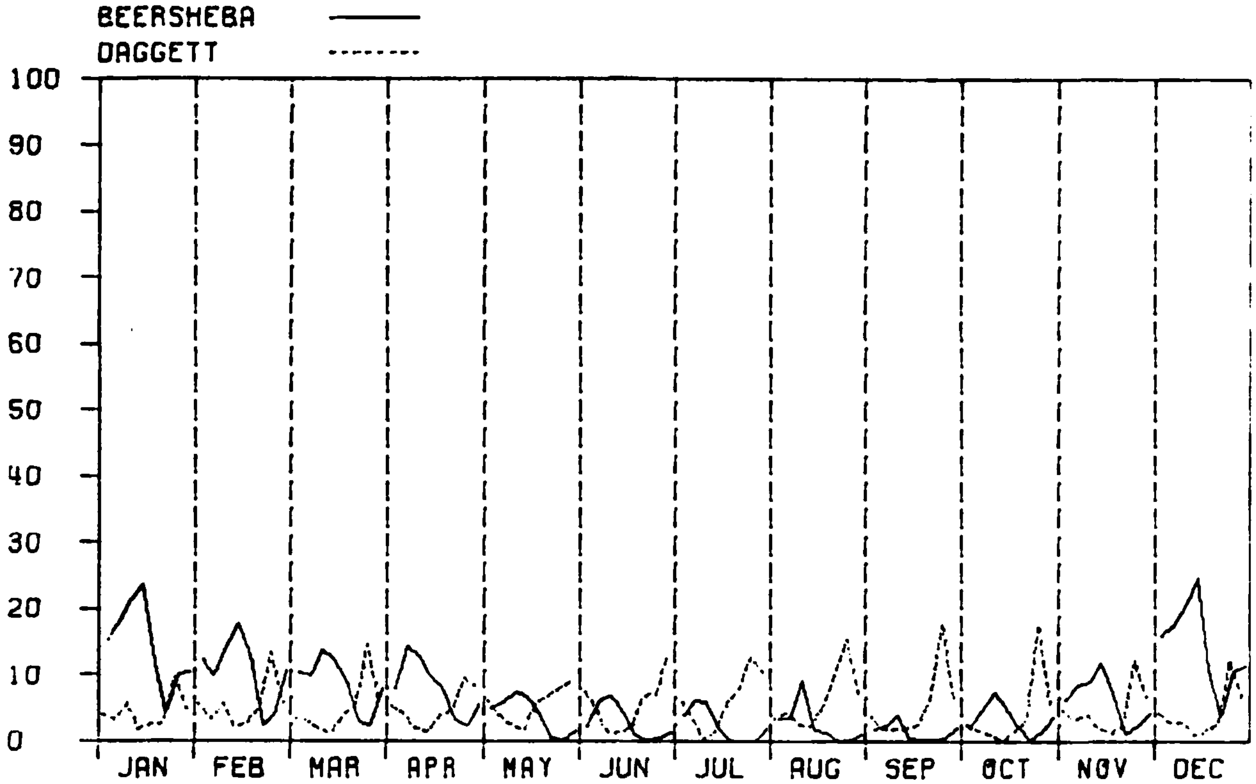



Fig. 24. (Cont'd) WIND DIRECTION
CLASS = SOUTH
FREQUENCY (IN PER CENT) . BY 3-HOURLY PERIOD AND BY MONTH



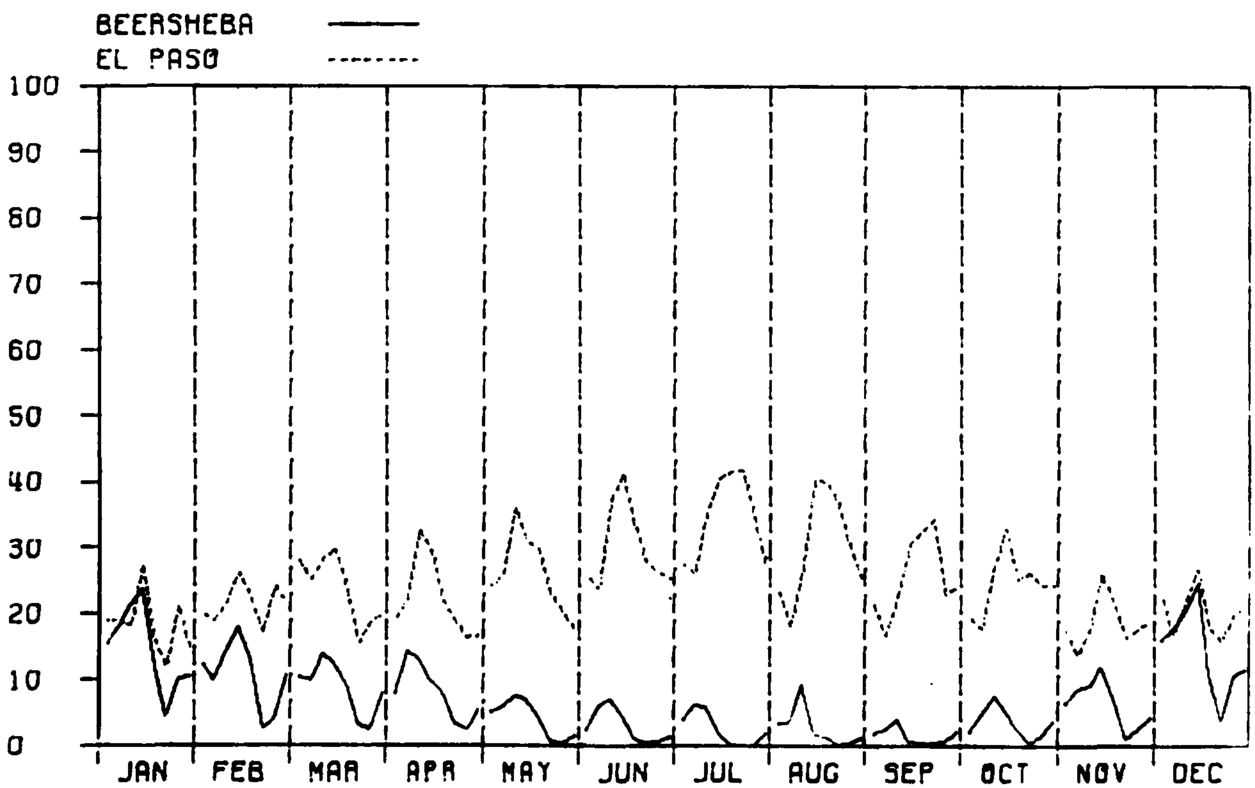
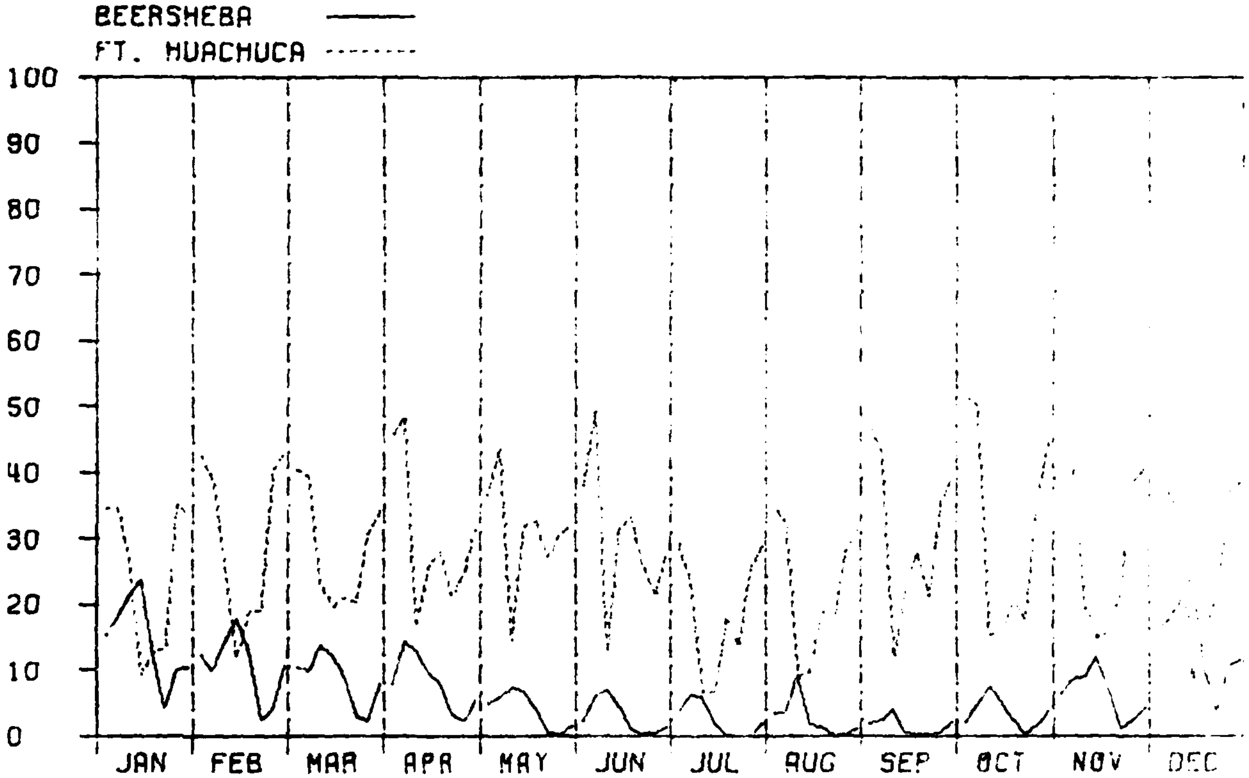



Fig. 24. (Cont'd) WIND DIRECTION
CLASS = SOUTH
FREQUENCY (IN PER CENT), BY 3-HOURLY PERIOD AND BY MONTH



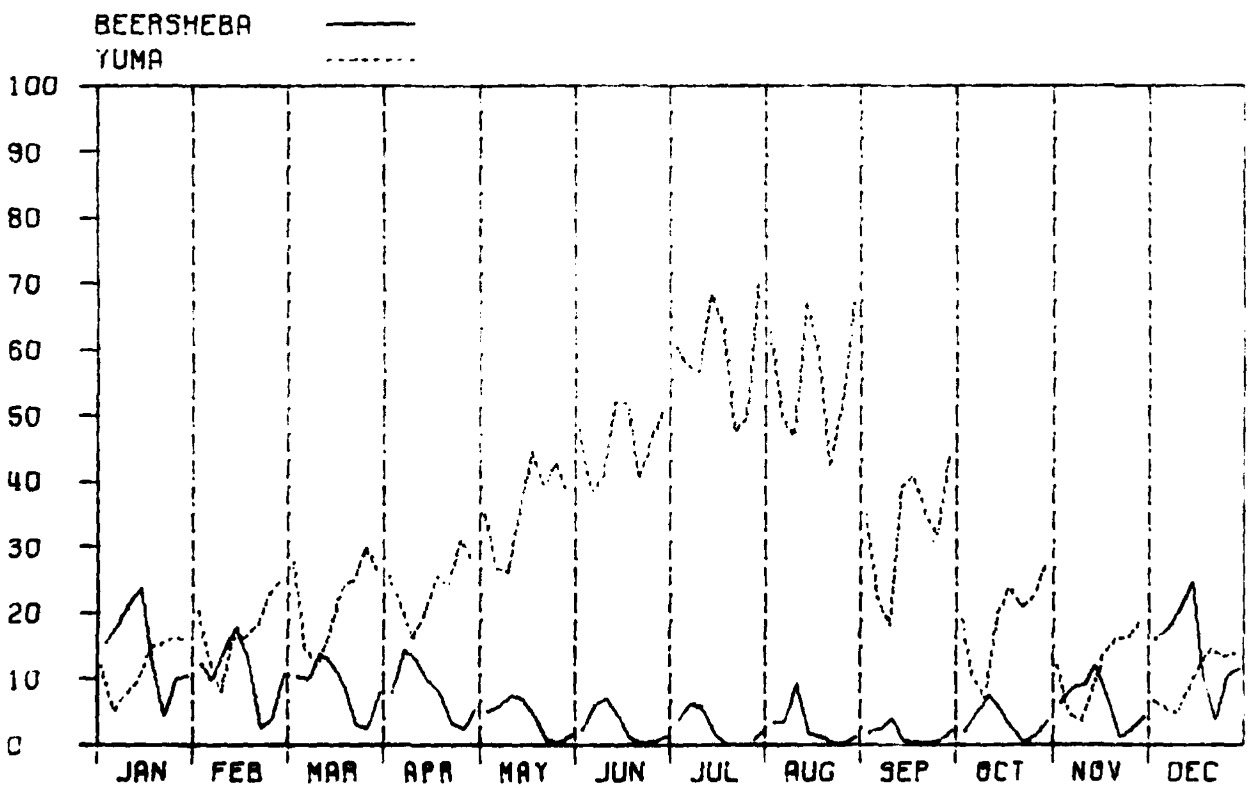
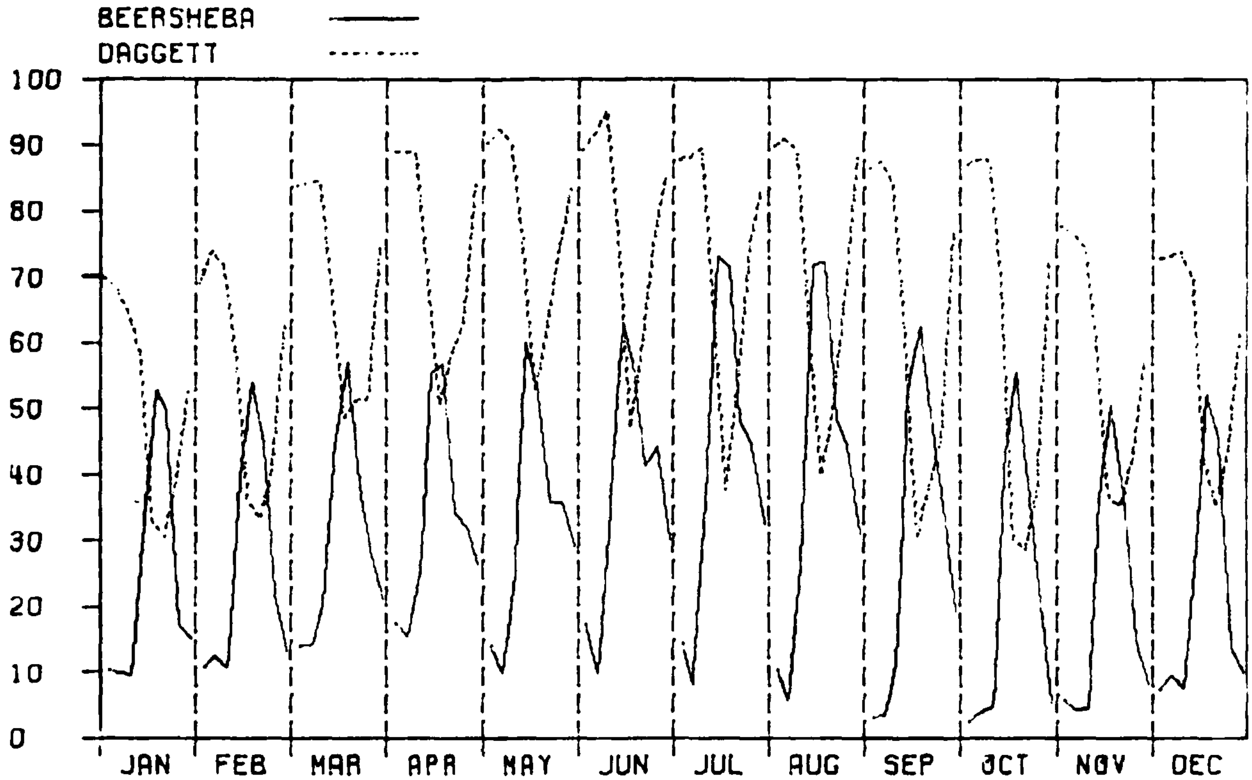



Fig. 24. (Cont'd) WIND DIRECTION
CLASS = WEST
FREQUENCY (IN PER CENT). BY 3-HOURLY PERIOD AND BY MONTH



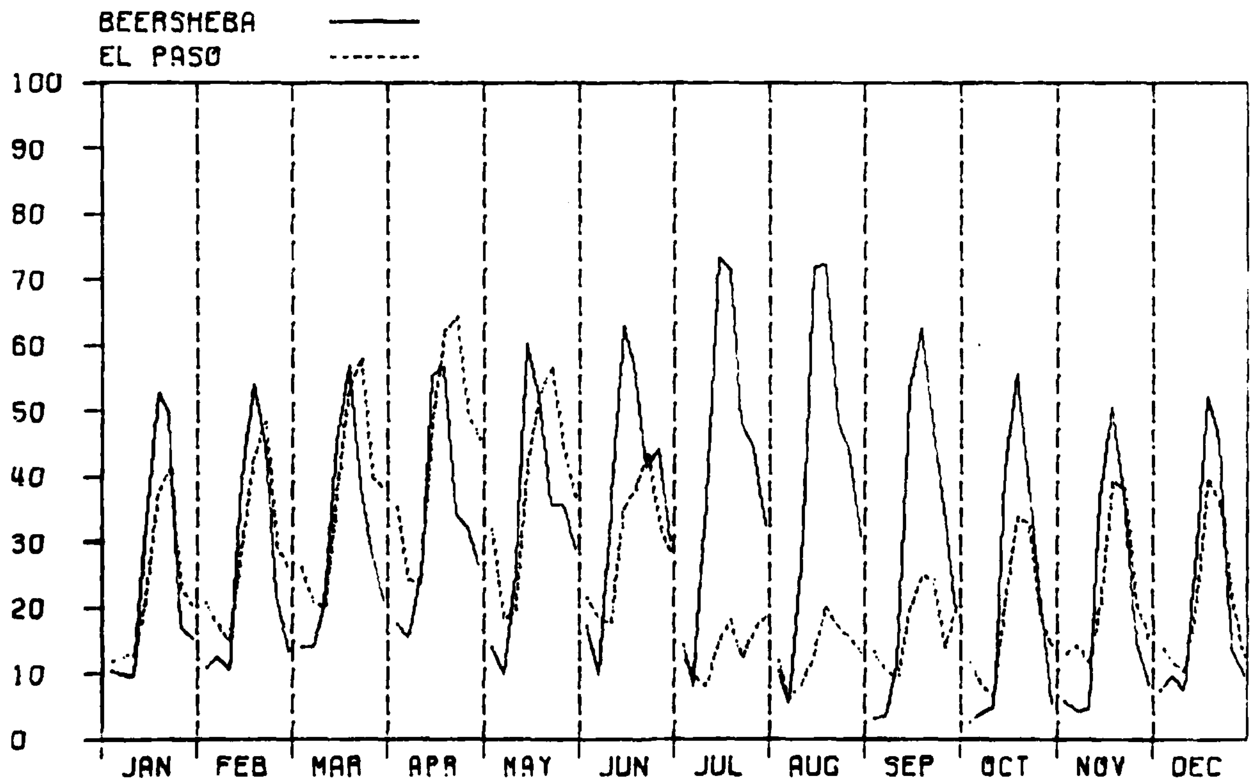
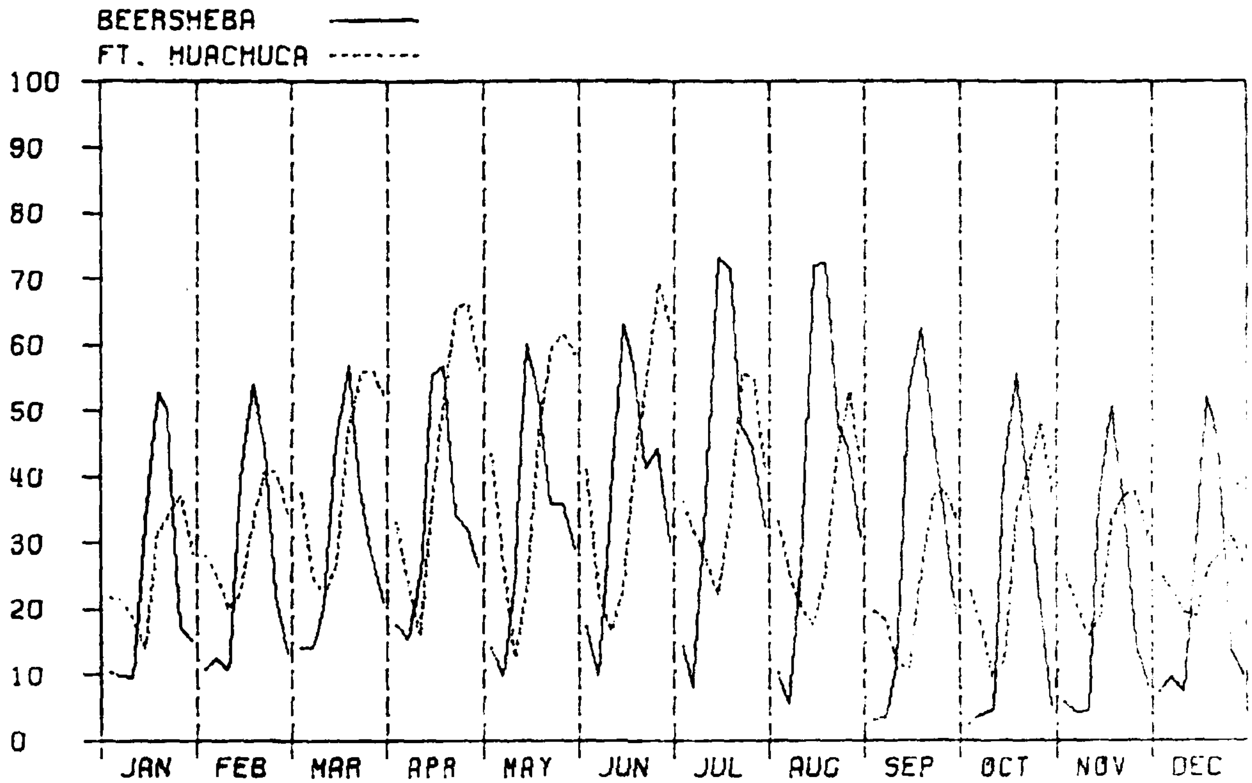



Fig. 24. (Cont'd) WIND DIRECTION

CLASS = WEST

FREQUENCY (IN PER CENT). BY 3-HOURLY PERIOD AND BY MONTH



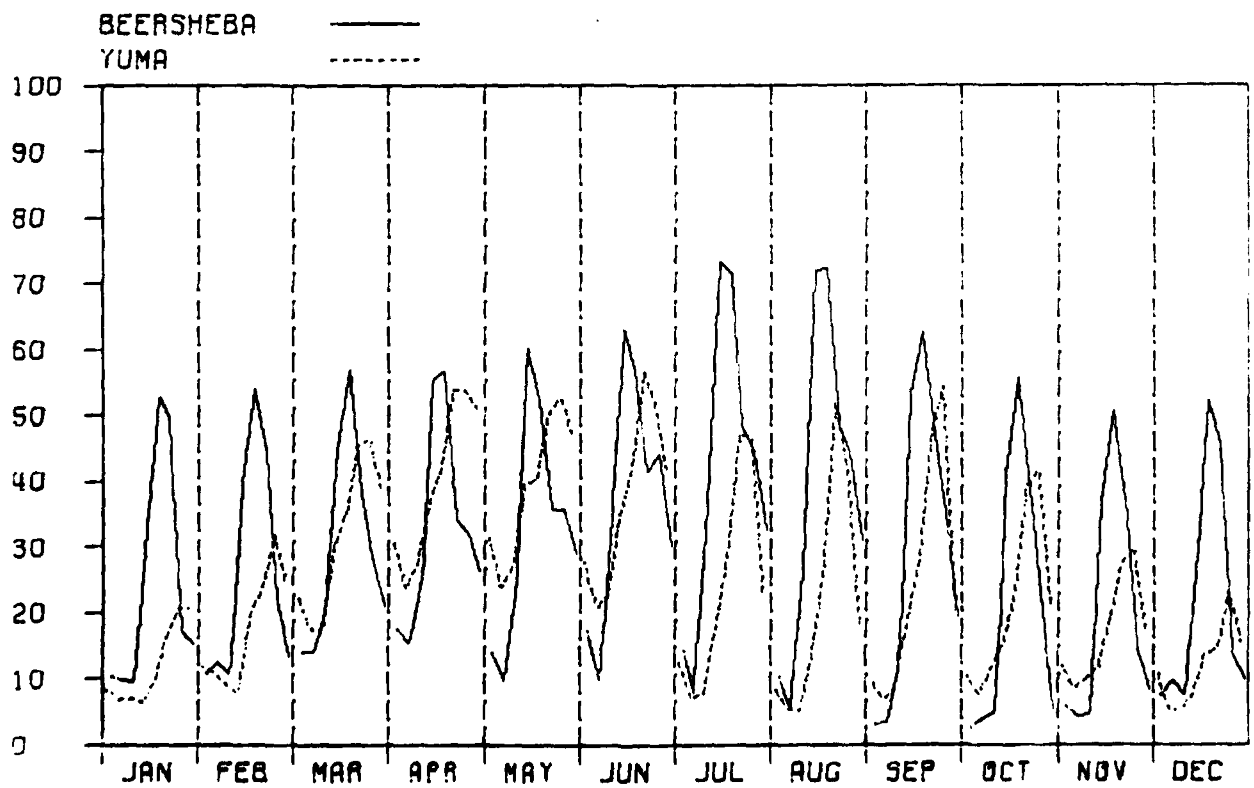



Fig. 25. WIND DIRECTION
CLASS = CALM
FREQUENCY (IN PER CENT), BY MONTH

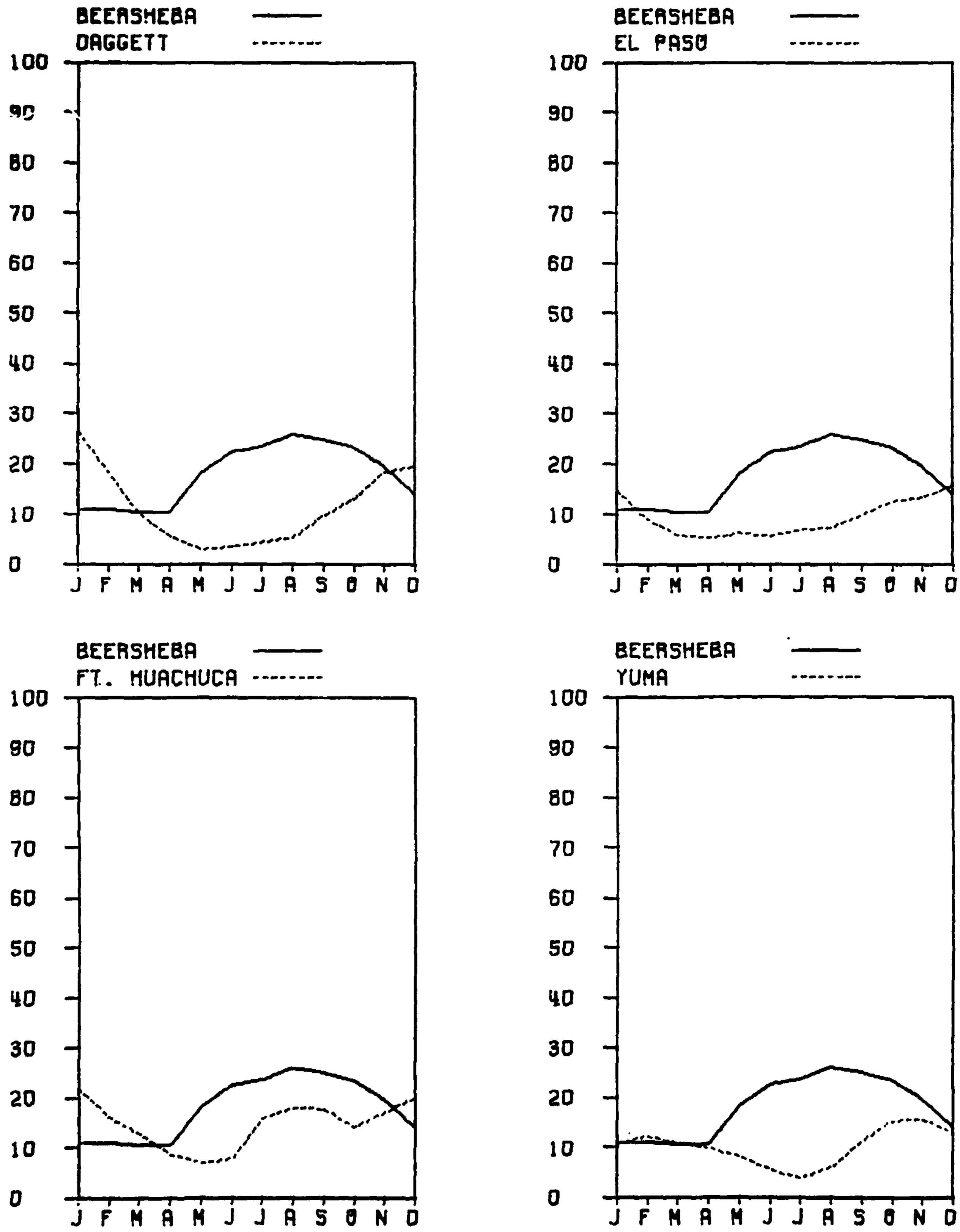
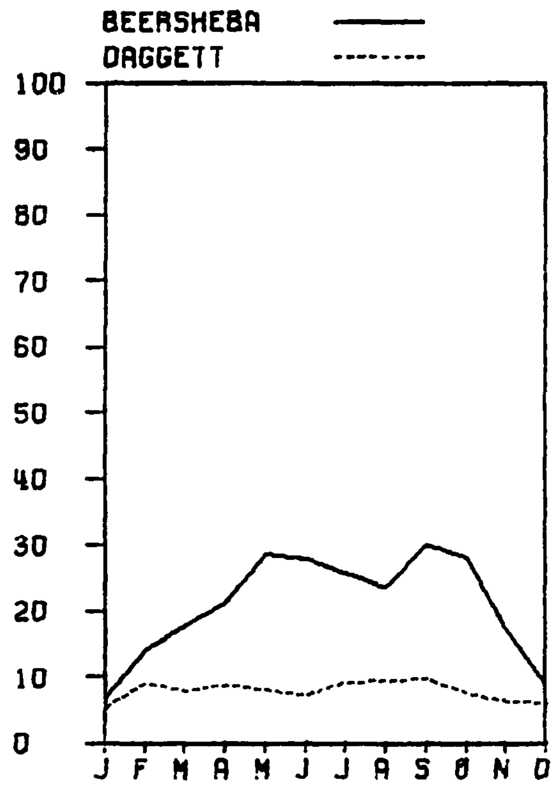
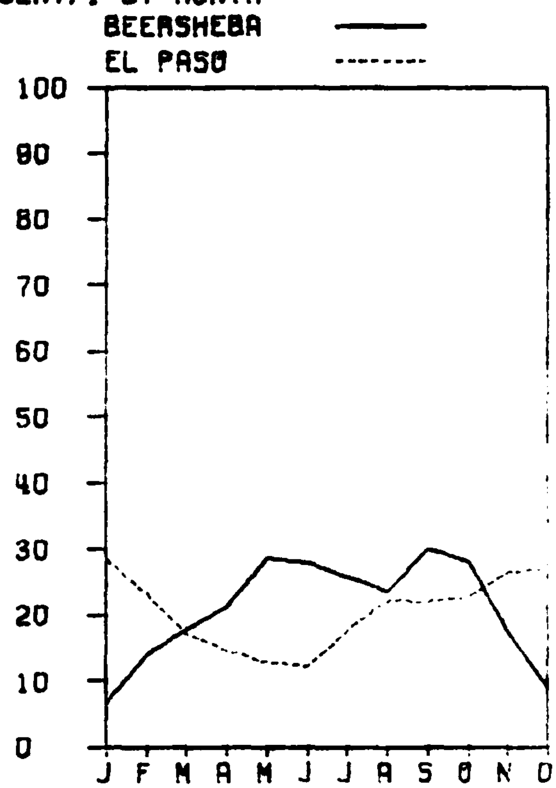
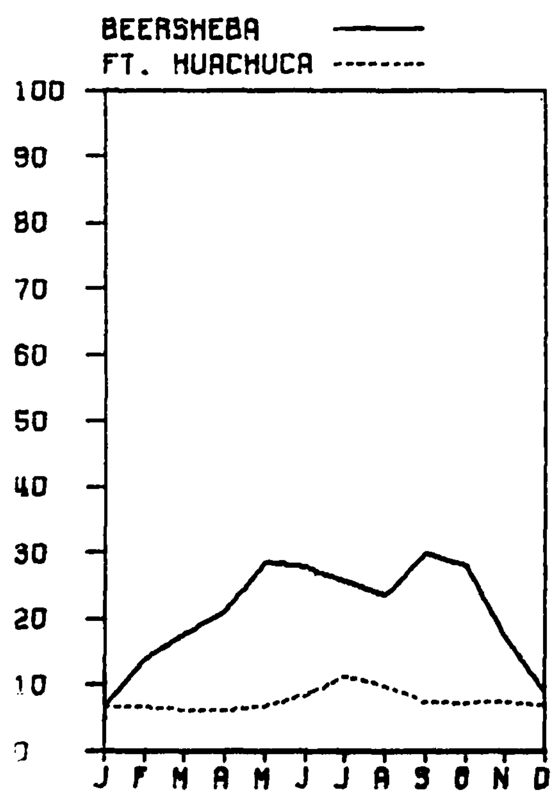


Fig. 25. (Cont'd) WIND DIRECTION
CLASS = NORTH
FREQUENCY (IN PER CENT), BY MONTH



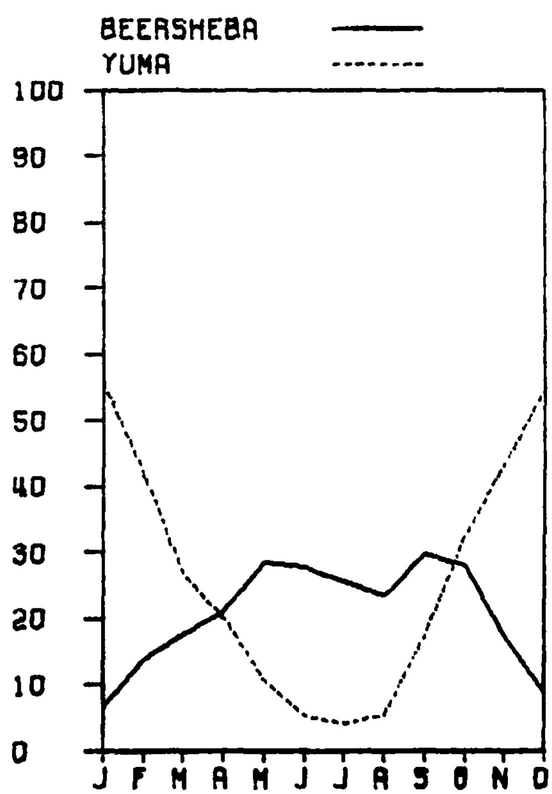



Fig. 25. (Cont'd) WIND DIRECTION
CLASS = EAST
FREQUENCY (IN PER CENT), BY MONTH

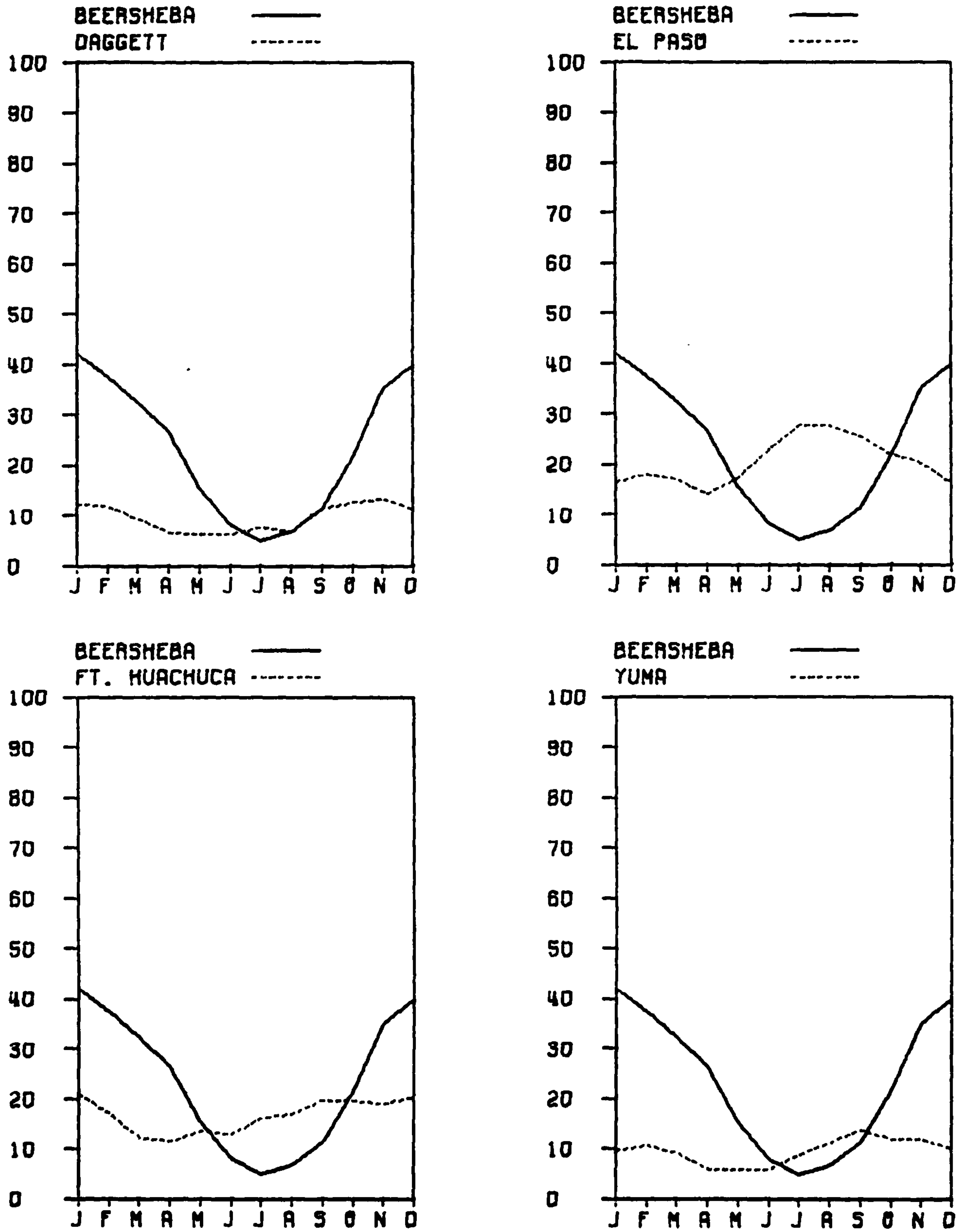


Fig. 25. (Cont'd) WIND DIRECTION
CLASS = SOUTH
FREQUENCY (IN PER CENT), BY MONTH

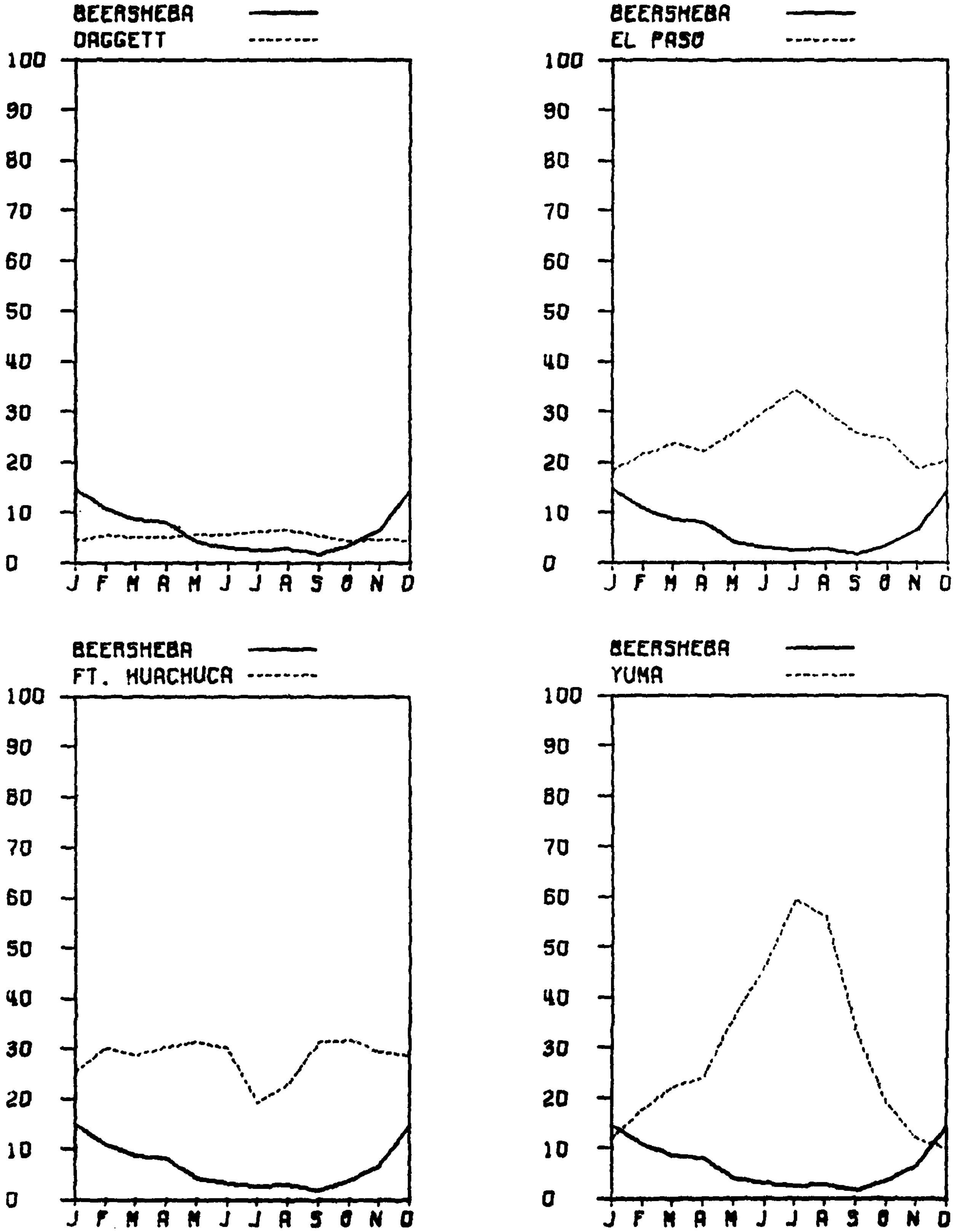
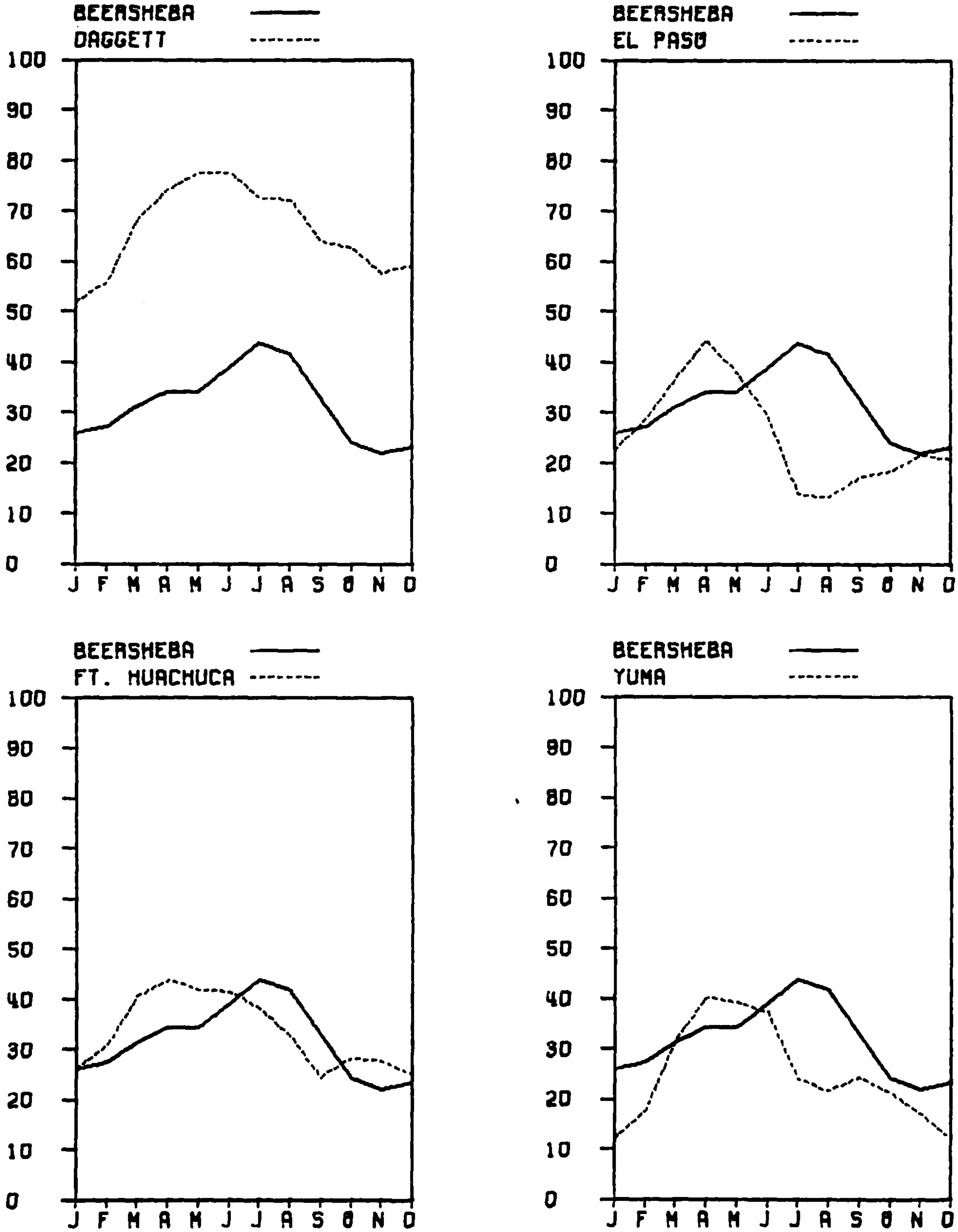


Fig. 25. (Cont'd) WIND DIRECTION
CLASS = WEST
FREQUENCY (IN PER CENT), BY MONTH



E. Absolute Humidity

The absolute humidity (density of water vapor) is calculated from the equation of state for pure water vapor

$$\rho_w = \frac{e_w}{R_w T}$$

where $T$ absolute temperature of the water vapor (which in a mixture is the dew point).

$e_w$ saturation vapor pressure over water at temperature $T$

$R_w$ gas constant for water vapor = $4.6150 \times 10^6$ erg $gm^{-1}$ $K^{-1}$.

When $\rho_w$ is in gm $m^{-3}$ and $e_w$ is in mb, the formula becomes

$$\rho_w = 216.68 \frac{e_w}{T}.$$

When there is a mixture of water vapor and dry air $e_w$ can be obtained from Tetens' empirical formula [11]

$$e_w(\text{mb}) = 6.11 \times 10^{at/(b+t)}$$

where $t$ dew point in degrees Celsius

$a$ 7.5

$b$ 237.3C.

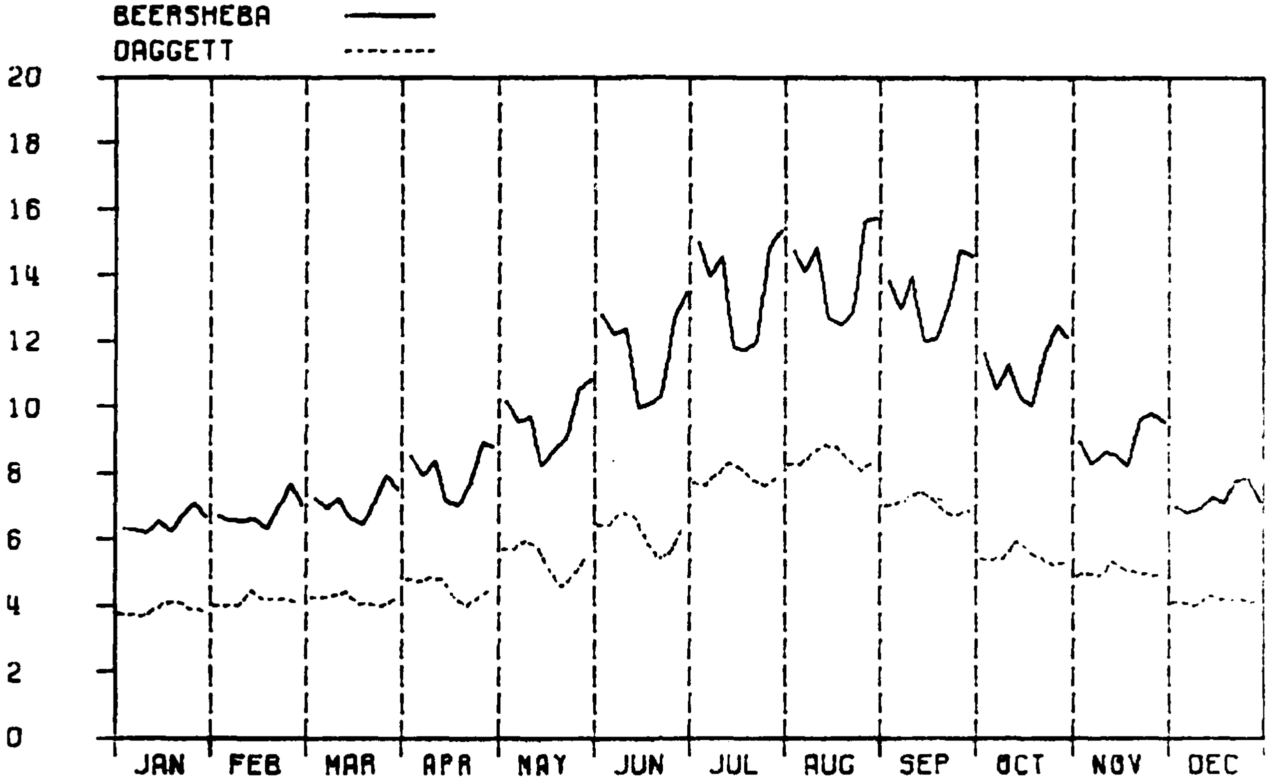
Table 8 is a comparison of saturation vapor pressures from Tetens' formula with those from the complex *Goff-Gratch* formula [12], considered to be the standard. Only at temperatures less than about -25C does the error in using Tetens' formula exceed 1%.

Table 8. Saturation vapor pressure over water computed from Tetens' formula [11] and from the Goff-Gratch formula [12].

| t(C) | $e_s$(mb)(Tetens) | $e_s$(mb)(Goff-Gratch) | Error(%) |
|---|---|---|---|
| -40 | .1843 | .1891 | -2.5 |
| -30 | .5019 | .5088 | -1.4 |
| -20 | 1.2467 | 1.2540 | -0.6 |
| -10 | 2.8581 | 2.8627 | -0.2 |
| 0 | 6.1078 | 6.11 | -0.04 |
| 10 | 12.283 | 12.272 | +0.04 |
| 20 | 23.389 | 23.373 | +0.07 |
| 30 | 42.442 | 42.430 | +0.03 |
| 40 | 73.777 | 73.777 | +0.00 |

Figs. 26 and 27 show the 3-hourly absolute humidities by month and the monthly means and mean daily maxima and minima by month. The latter two equations were used to compute absolute humidity. Since $\rho_w$ is a unique function of dew point, the discussion given in Section V.B. for dew point applies equally well to absolute humidity.

Fig. 26. ABS. HUMIDITY - GMS/M3
3-HOURLY MEANS. BY MONTH



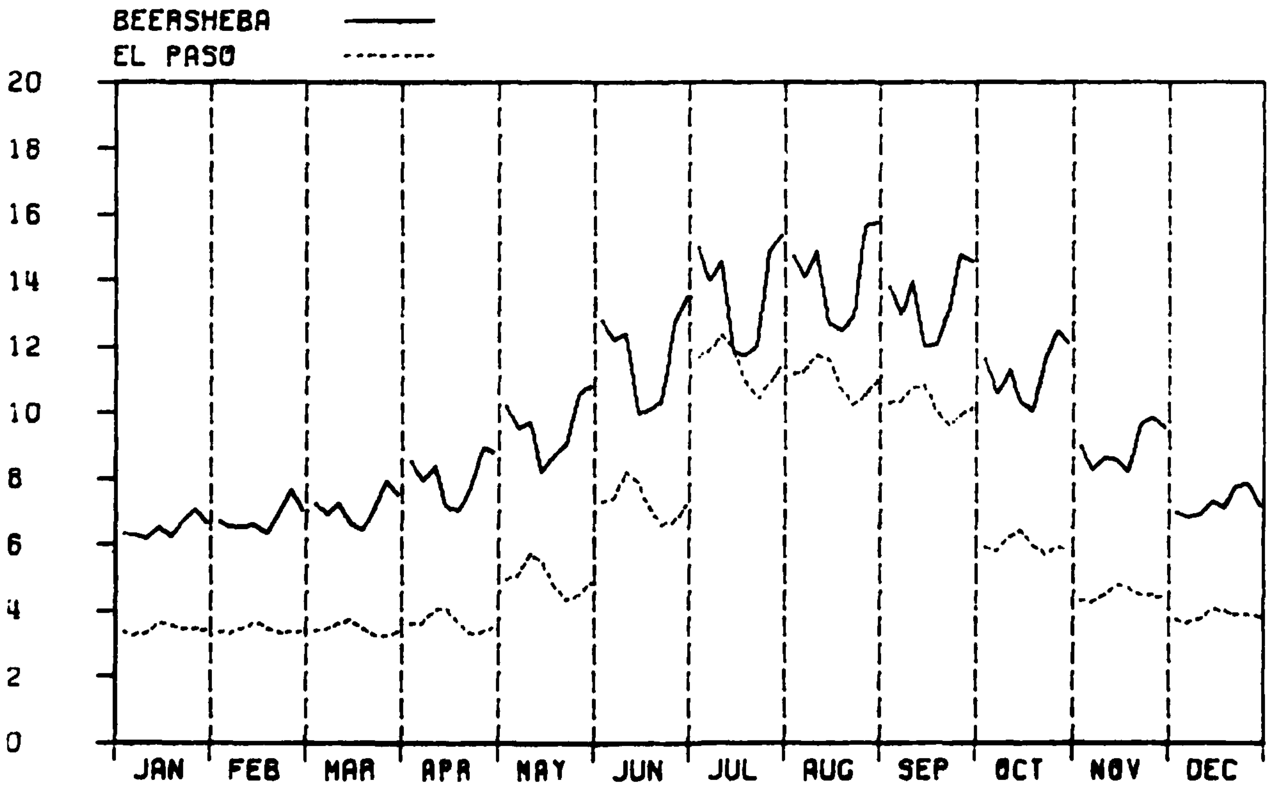
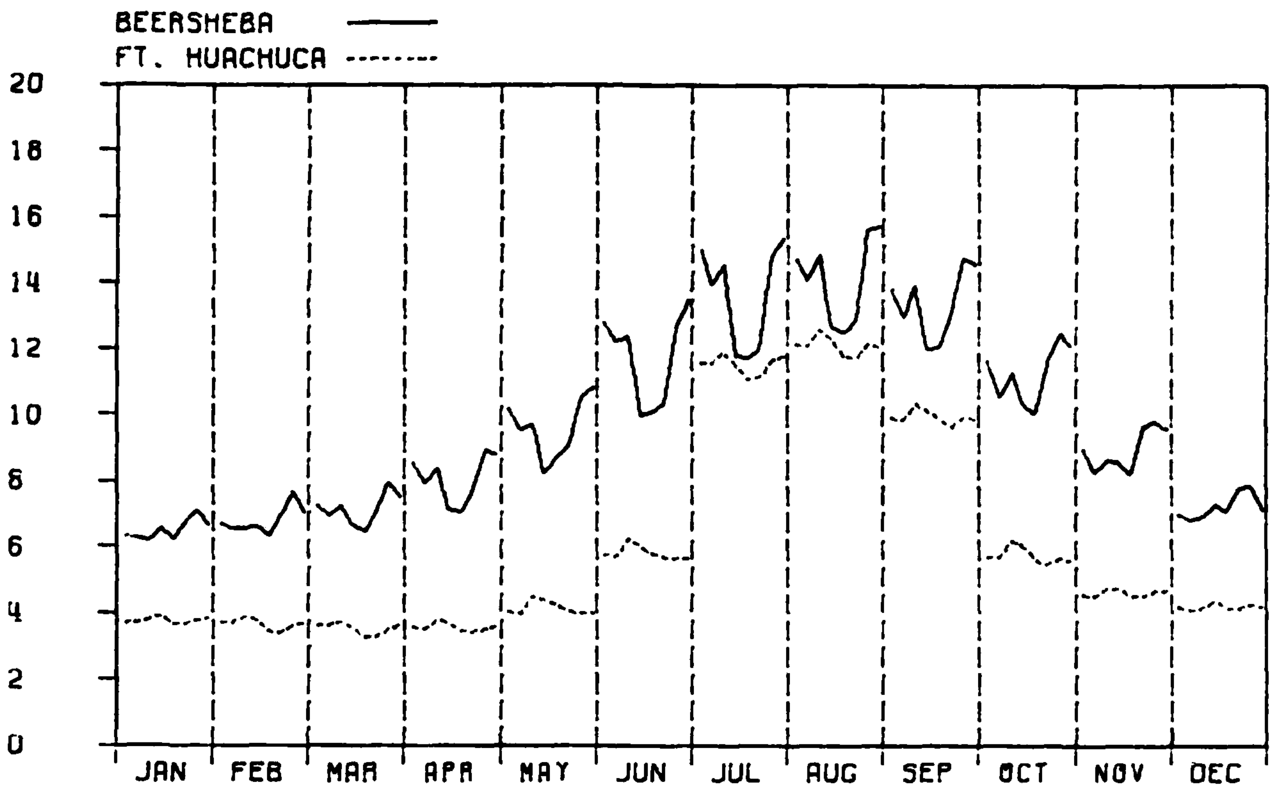



Fig. 26. (Cont'd) ABS. HUMIDITY - GMS/M3
3-HOURLY MEANS, BY MONTH



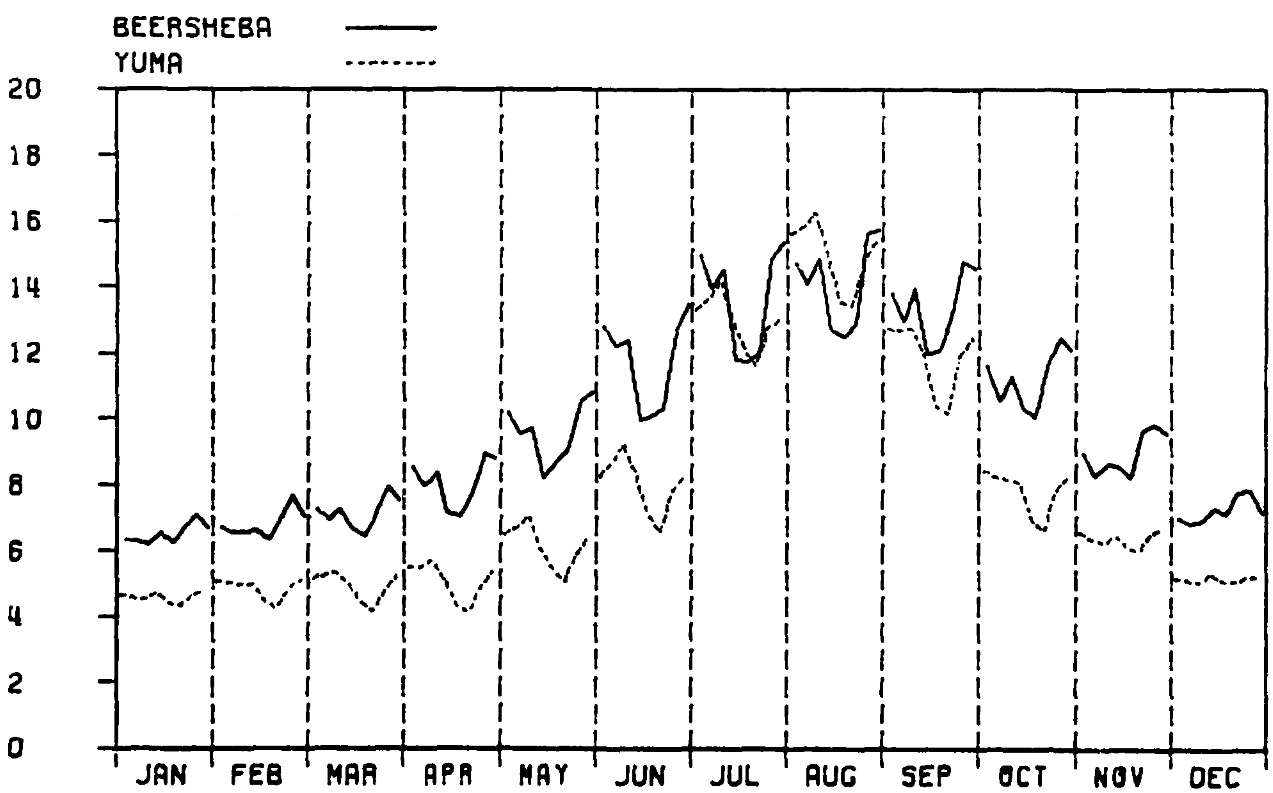
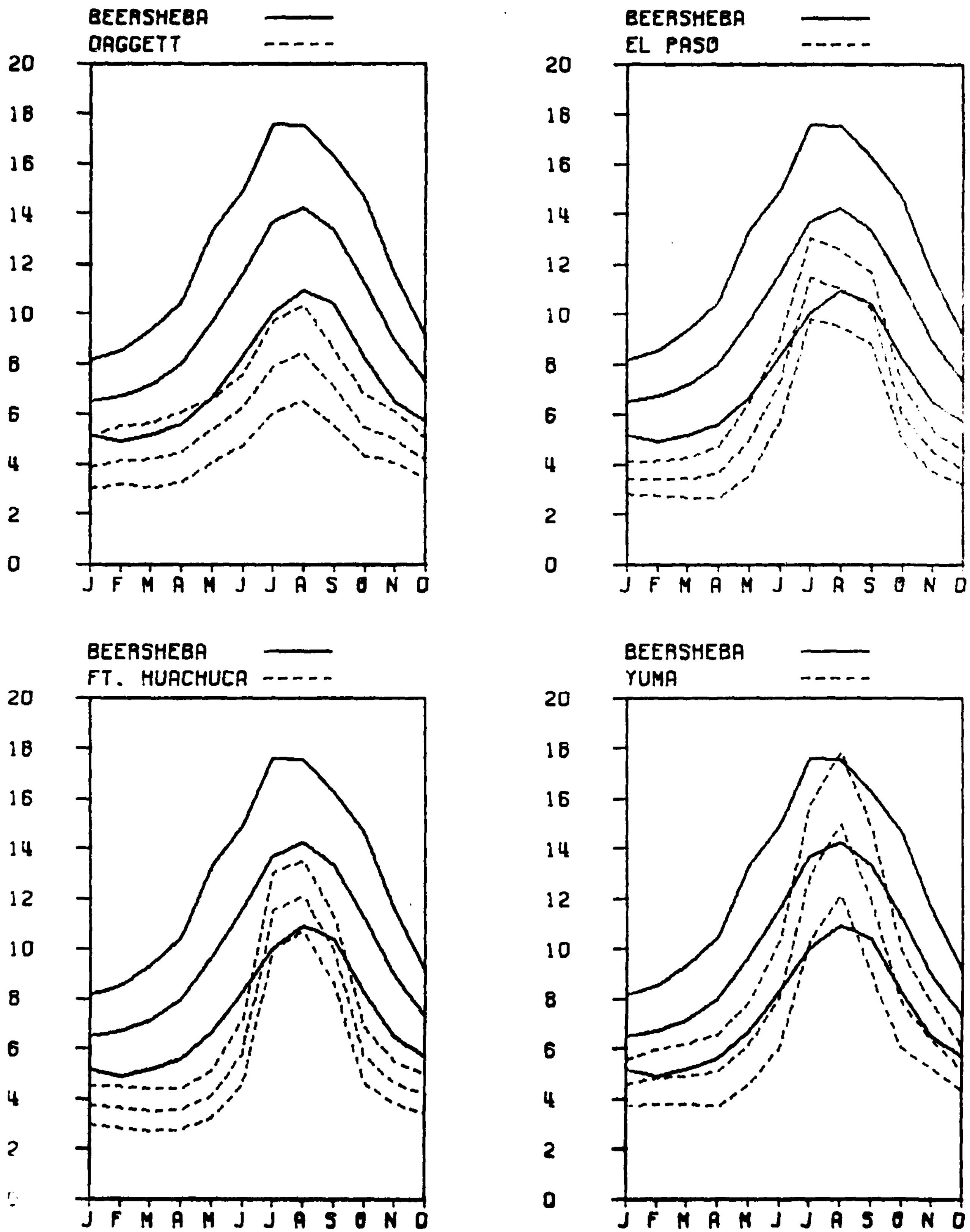



Fig. 27. ABS. HUMIDITY - GMS/M3
MONTHLY MEANS: MEAN DAILY MAXIMA AND MINIMA, BY MONTH



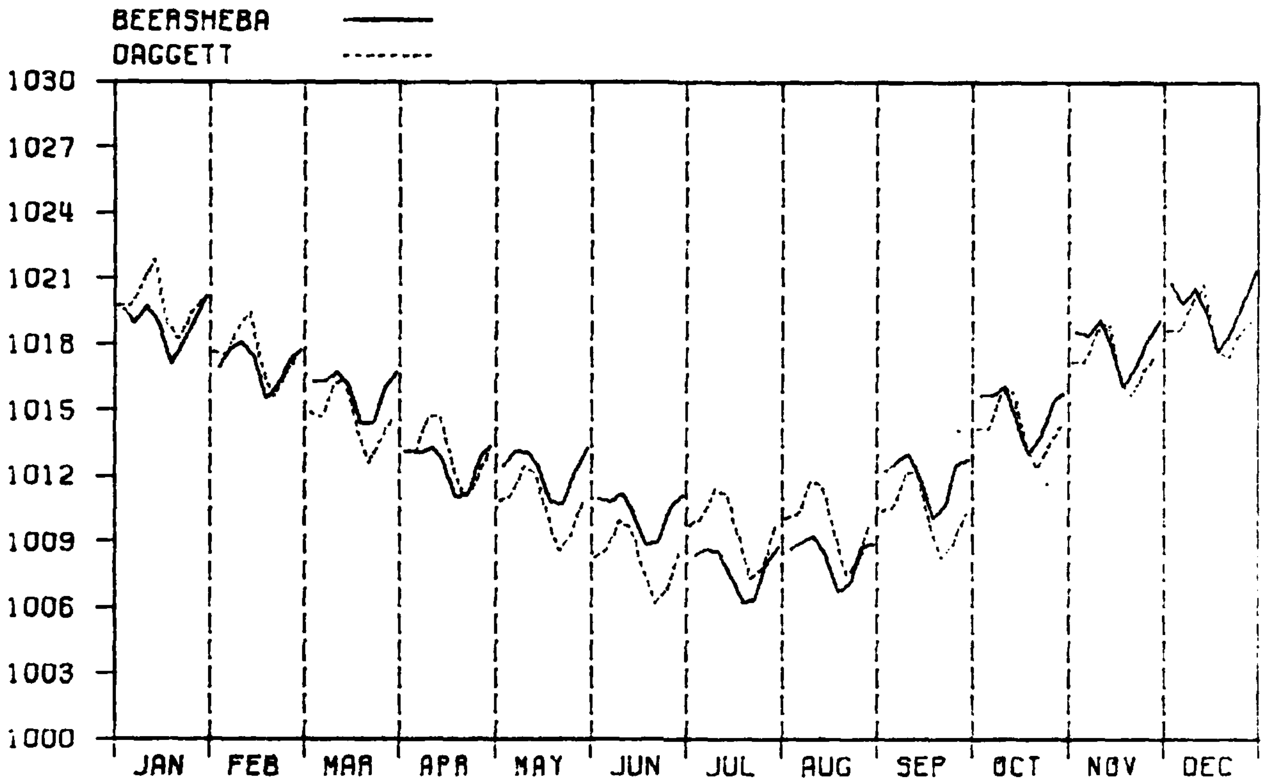
## F. Sea-level Pressure

Sea-level pressure data at Beersheba were sporadic until 1 July 1971 when they became quite frequent. As a result, the effective record length of pressure was about 6 years in contrast to 10 years at the U.S. stations.

Fig. 28 shows the 3-hourly means by month of sea-level pressure for the five stations. The daily range in pressure varies from about 3 to 5 mb among the five stations. There is no obvious connection between the magnitude of daily range and the seasons. The times of daily maxima and daily minima are essentially the same at all stations. The diurnal pressure wave is easily discernible, while the semi-diurnal wave is usually less clear.

The monthly means, mean daily maxima and minima are presented in Fig. 29. The annual range of mean monthly pressure varies from 8 to 12 mb among all stations, with the highest pressure occurring in December or January and the lowest pressure in June or July. The U.S. stations show a characteristic rise in pressure in July and August that is not present at Beersheba. The average annual pressure is approximately the same at all stations except Ft. Huachuca where it is a couple of mb less. The mean daily maxima and minima are separated from the monthly mean by 2 to 3 mb.

Fig. 28. SEA LEVEL PRESSURE - MB
3-HOURLY MEANS. BY MONTH



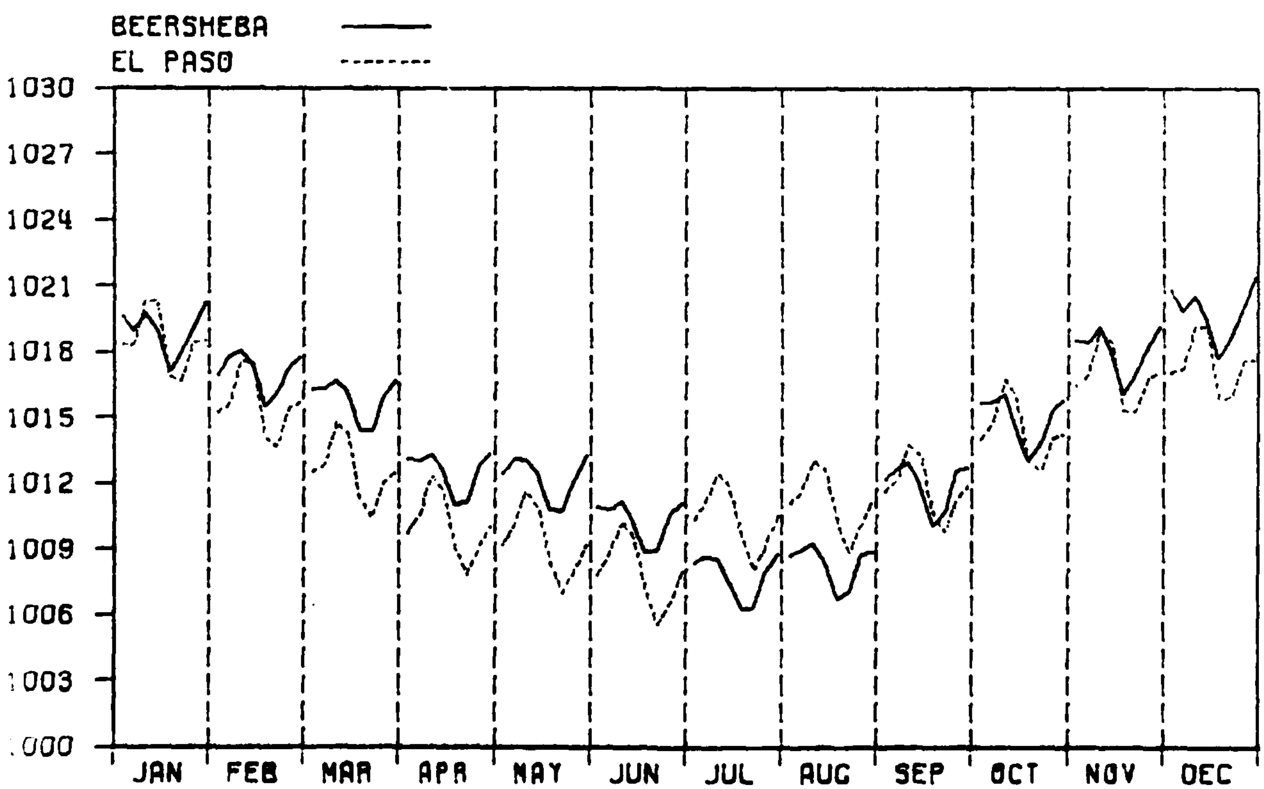
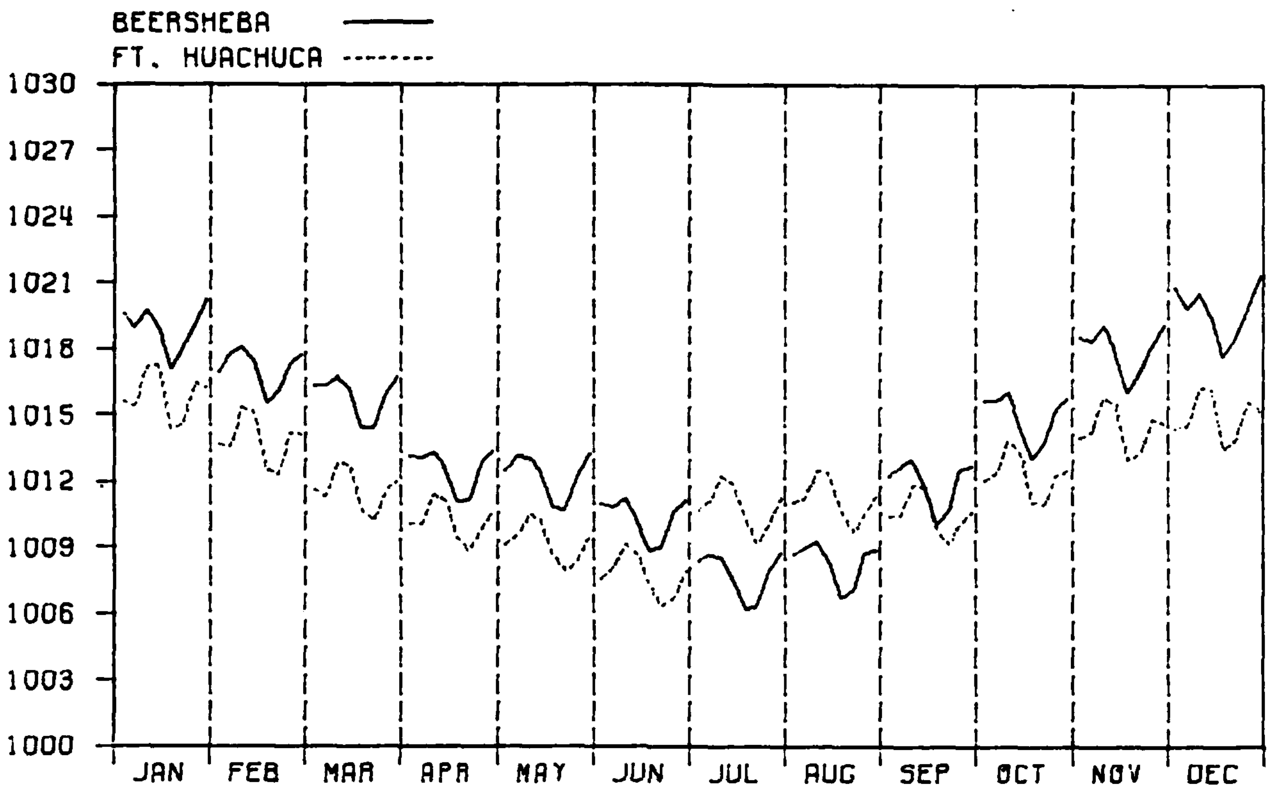



Fig. 28. (Cont'd) SEA LEVEL PRESSURE - MB
3-HOURLY MEANS. BY MONTH



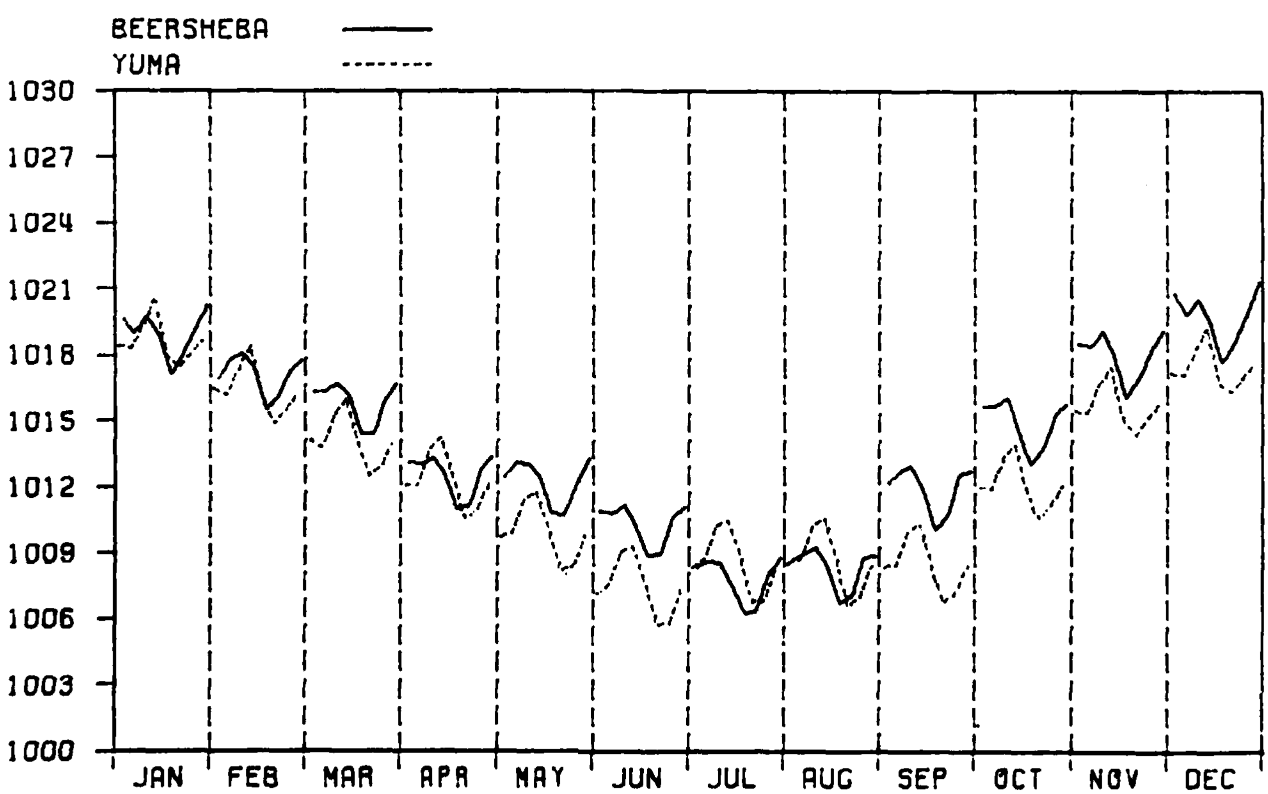
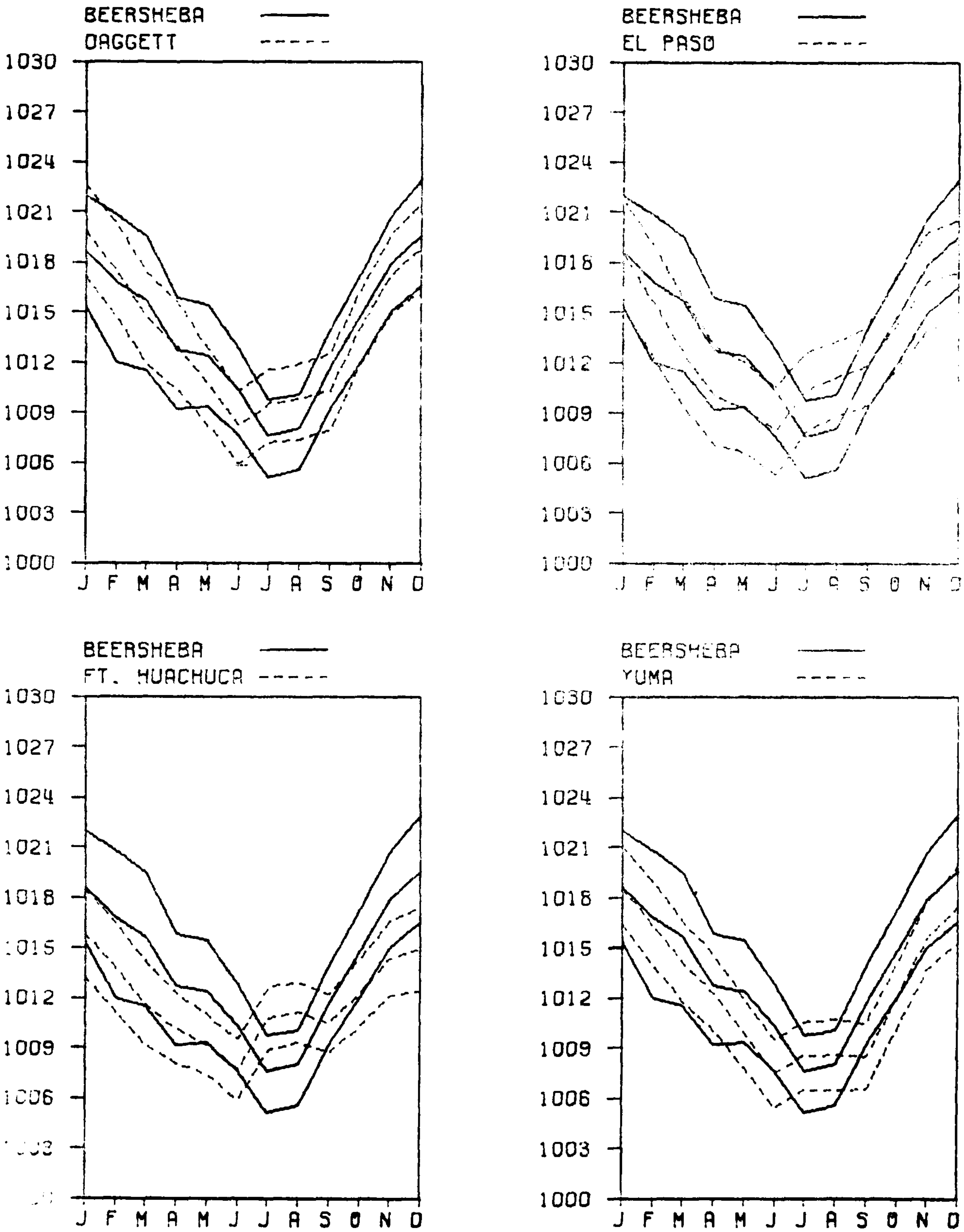



Fig. 29. SEA LEVEL PRESSURE - MB
MONTHLY MEANS: MEAN DAILY MAXIMA AND MINIMA, BY MONTH



APPENDIX B

A. Introduction

The results of the analysis of two types of standard deviations are presented in Appendix B. The first type is the 3-hourly standard deviation by month and the second is the daily standard deviation by month. The respective formulas are given in IV.C. The variables for which they were computed are dry-bulb temperature, dew-point temperature, relative humidity, wind speed, stability, absolute humidity and sea-level pressure.

The 3-hourly standard deviations provide a measure of the variability of the day-to-day values of a particular variable about the mean for the month and hour selected. For example, in Fig. 30 that follows, the maximum 3-hourly standard deviation of dry-bulb temperature for April at Beersheba occurs around 1400 local mean solar time and the minimum around 0200. Thus the air temperature at 1400 from day-to-day fluctuates more than the air temperature at 0200. This could occur because of the greater variability in cloudiness at 1400 than at 0200. If the distribution of observed temperatures at 1400 were approximately normal, then the range between the mean temperature minus one standard deviation and the mean temperature plus one standard deviation includes about 68% of all the observations.

The daily standard deviation for a given month provides a measure of the daily range of a particular variable about

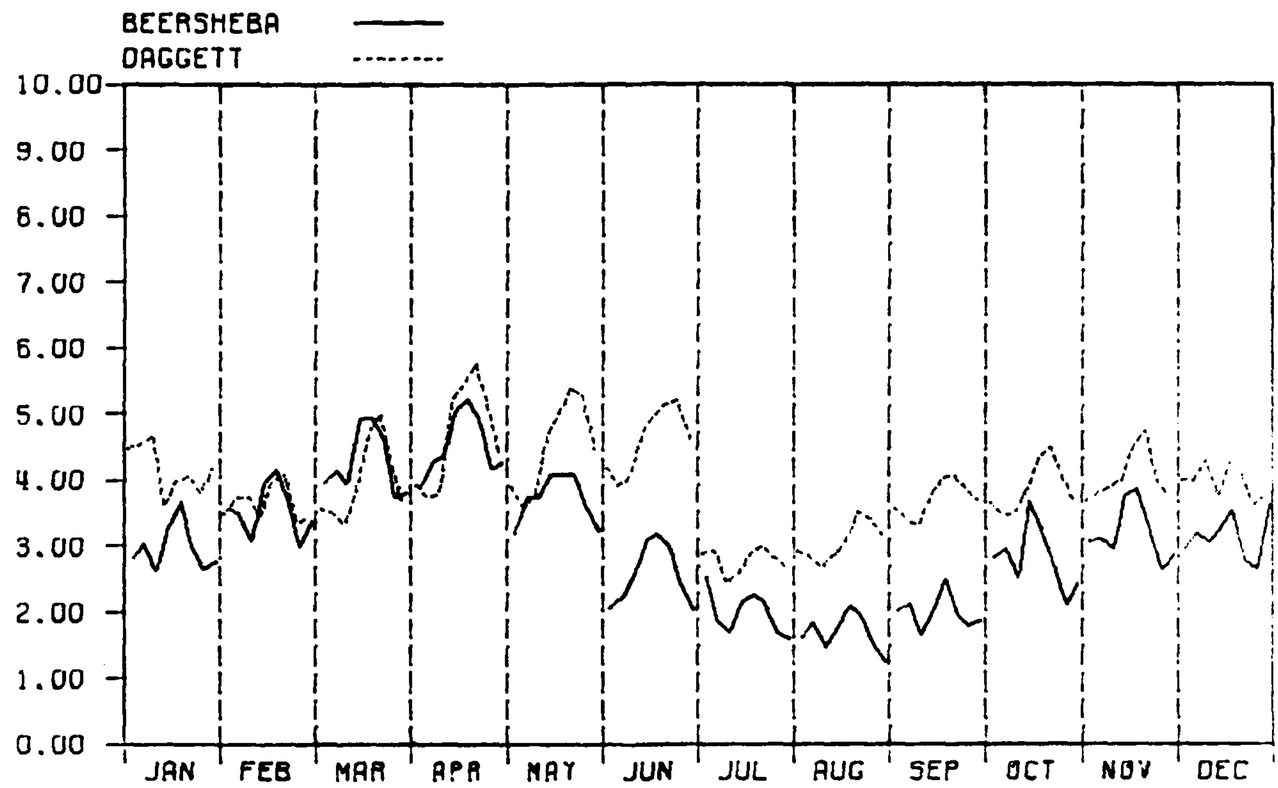
the daily mean. For example, in Fig. 31 that follows, the maximum daily standard deviation of dry-bulb temperature at Beersheba occurs in the spring months and the minimum standard deviation in the winter months. Thus, on the average, the daily range of dry-bulb temperature is greater in April than in December. This could be due to the greater amount of cloudiness in December than in April. The daily range is referred to rather than fluctuations about the daily mean because of the sinusoidal character of the daily dry-bulb temperature. All the variables discussed in Appendix B tend to have strong diurnal cycles. Thus, the standard deviation corresponds to approximately 71% of the amplitude of the diurnal wave.

There is no discussion given for the standard deviations of the variables that follow. The reasons are that the use of standard deviations in climatic comparisons is secondary in importance to means and they are used in ways that depend on the investigator's particular needs.

B. Dry-bulb Temperature

Figs. 30 and 31 show the 3-hourly and daily standard deviations by month for dry-bulb temperature.

Fig. 30. DRY BULB TEMP - DEG K
3-HOURLY STANDARD DEVIATIONS. BY MONTH



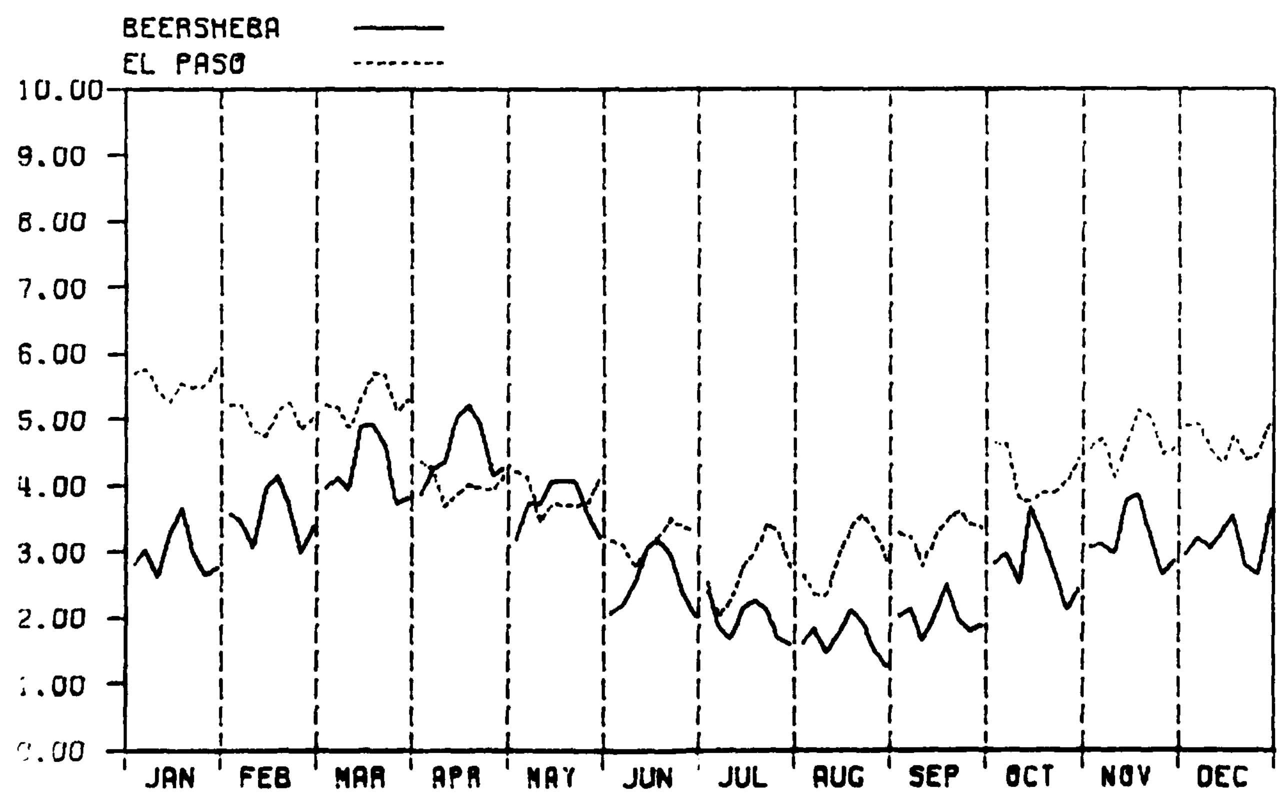
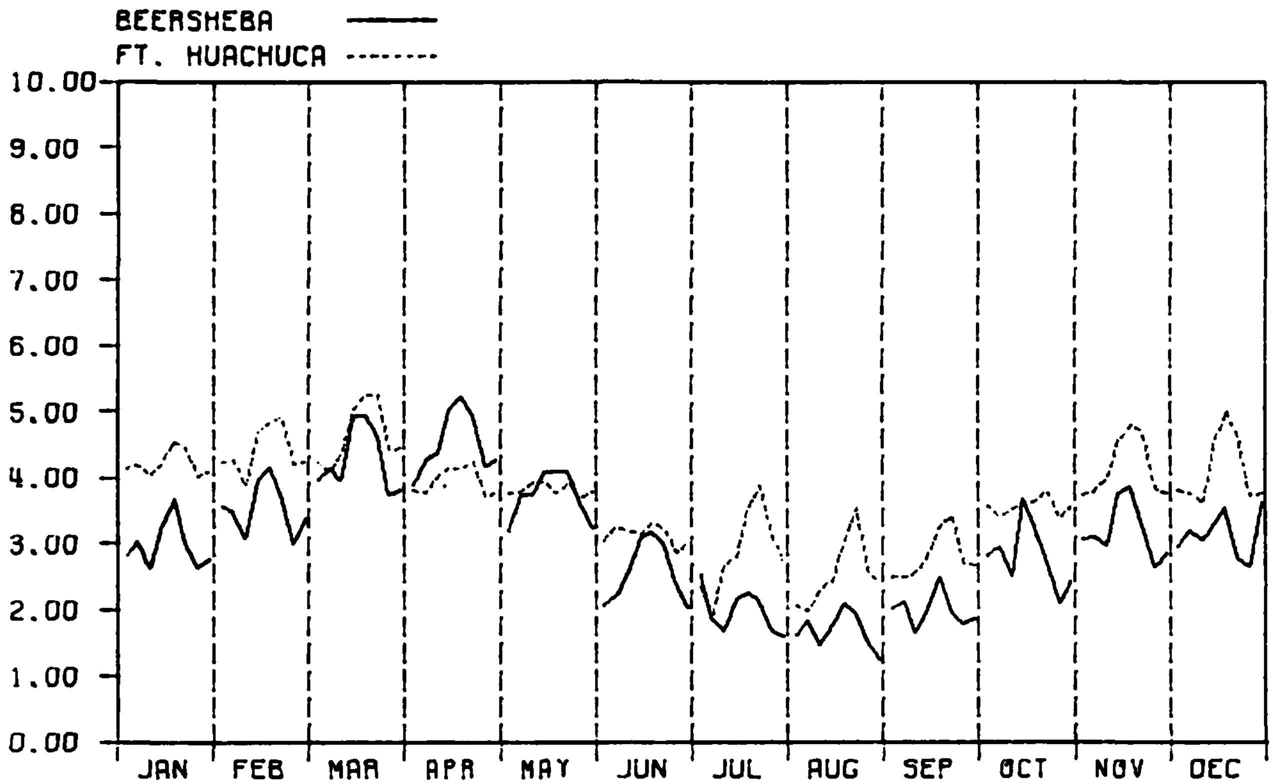



Fig. 30. (Cont'd) DRY BULB TEMP - DEG K
3-HOURLY STANDARD DEVIATIONS. BY MONTH



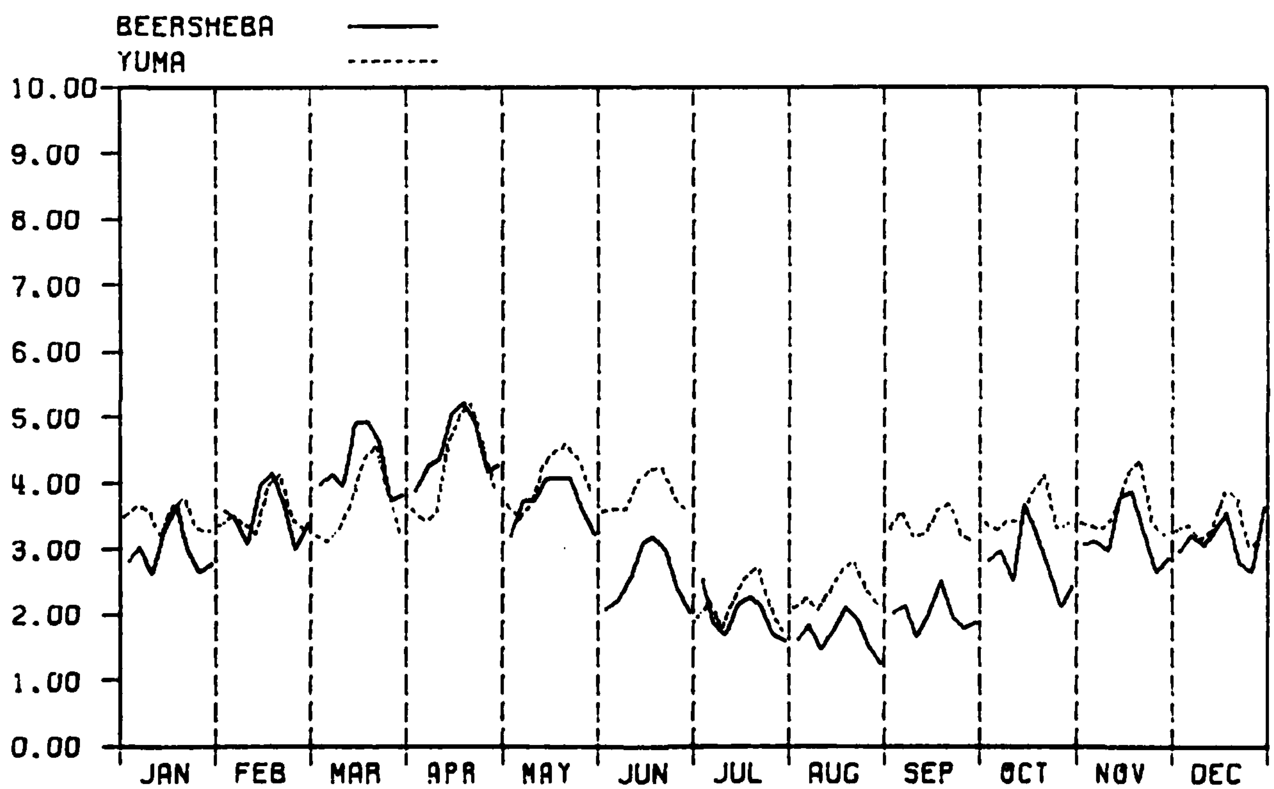
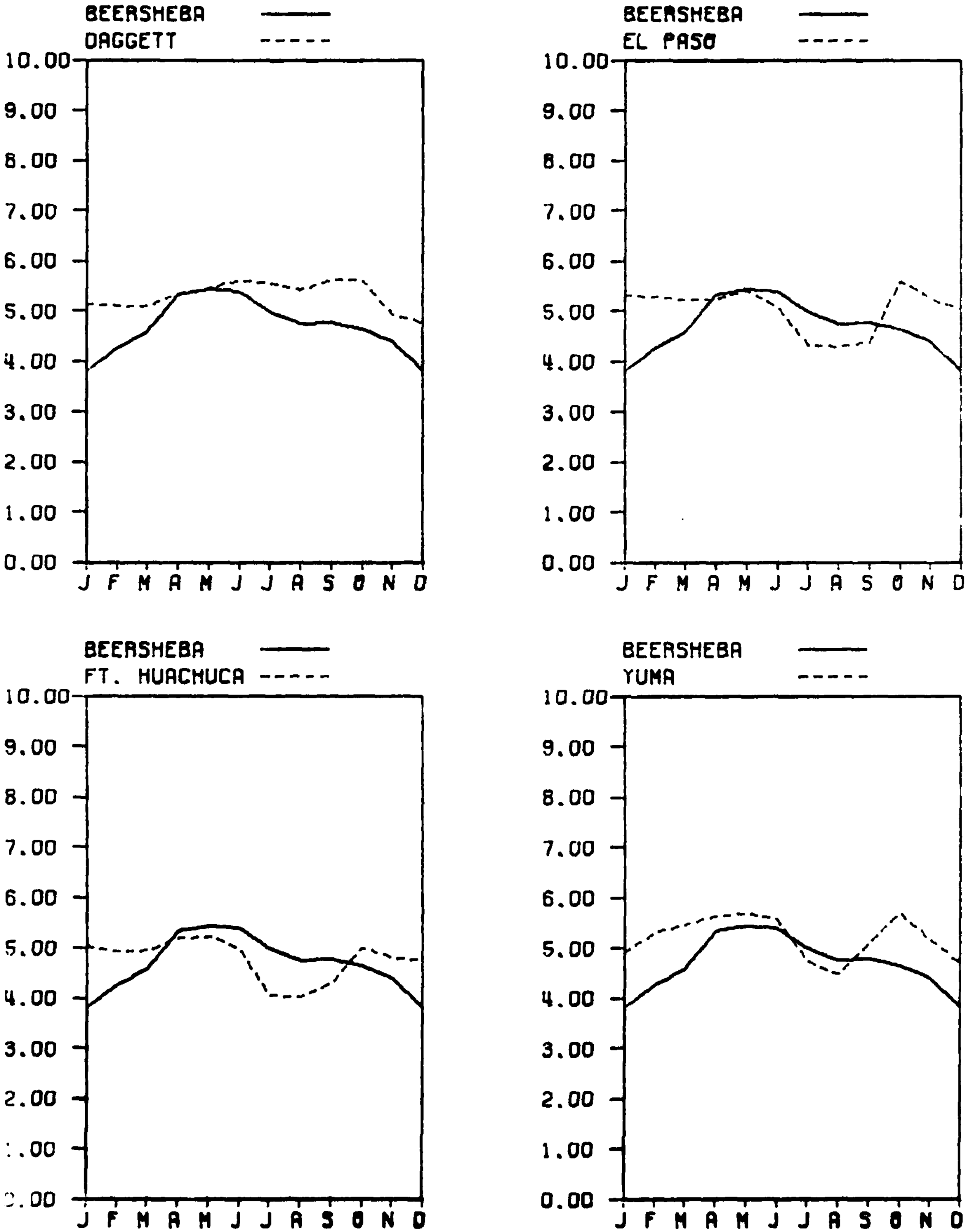



Fig. 31. DRY BULB TEMP - DEG K
DAILY STANDARD DEVIATIONS, BY MONTH



C. Dew-point Temperature

The 3-hourly and daily standard deviations by month for dew point are presented in Figs. 32 and 33.

Fig. 32. DEW POINT TEMP - DEG K
3-HOURLY STANDARD DEVIATIONS. BY MONTH

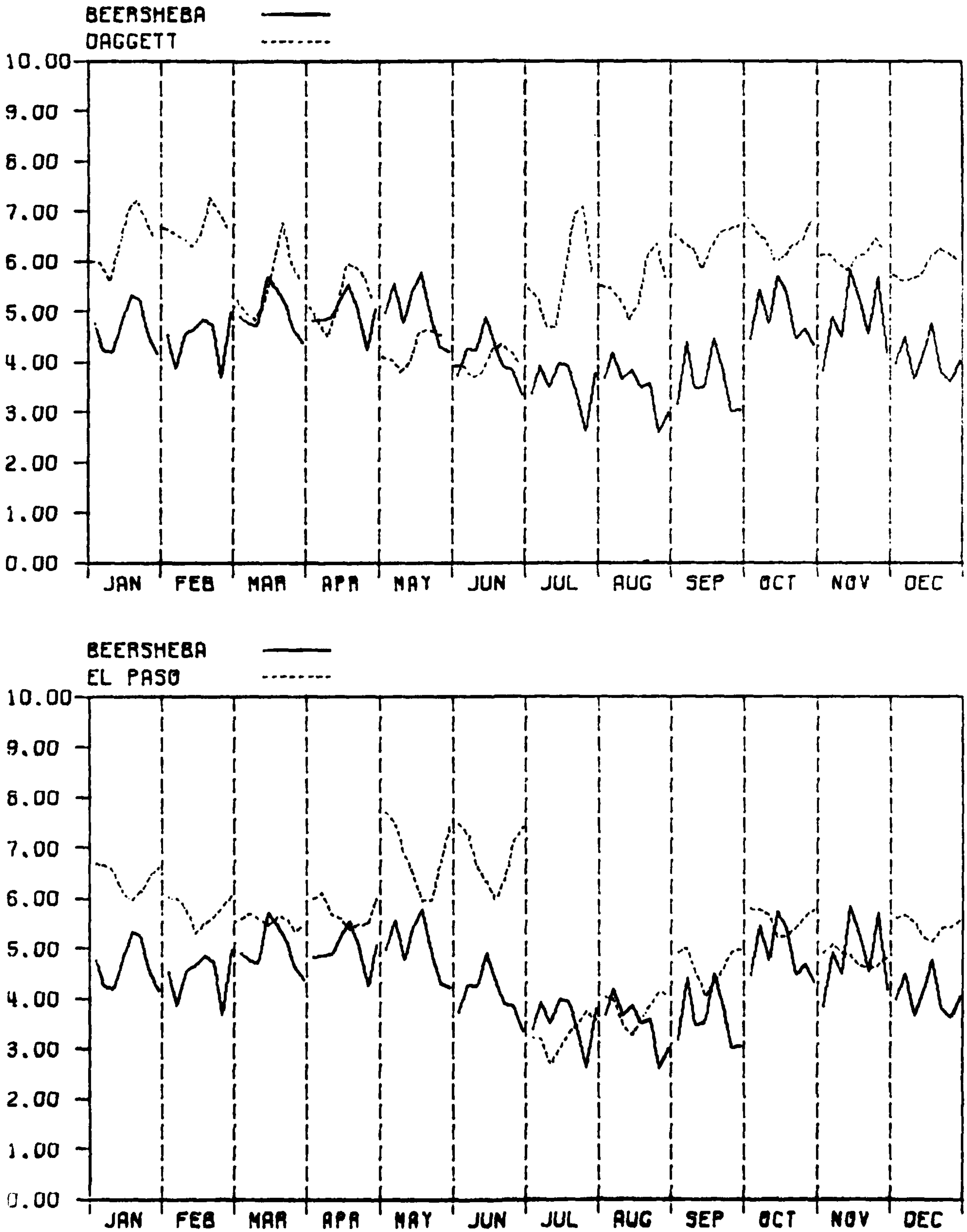
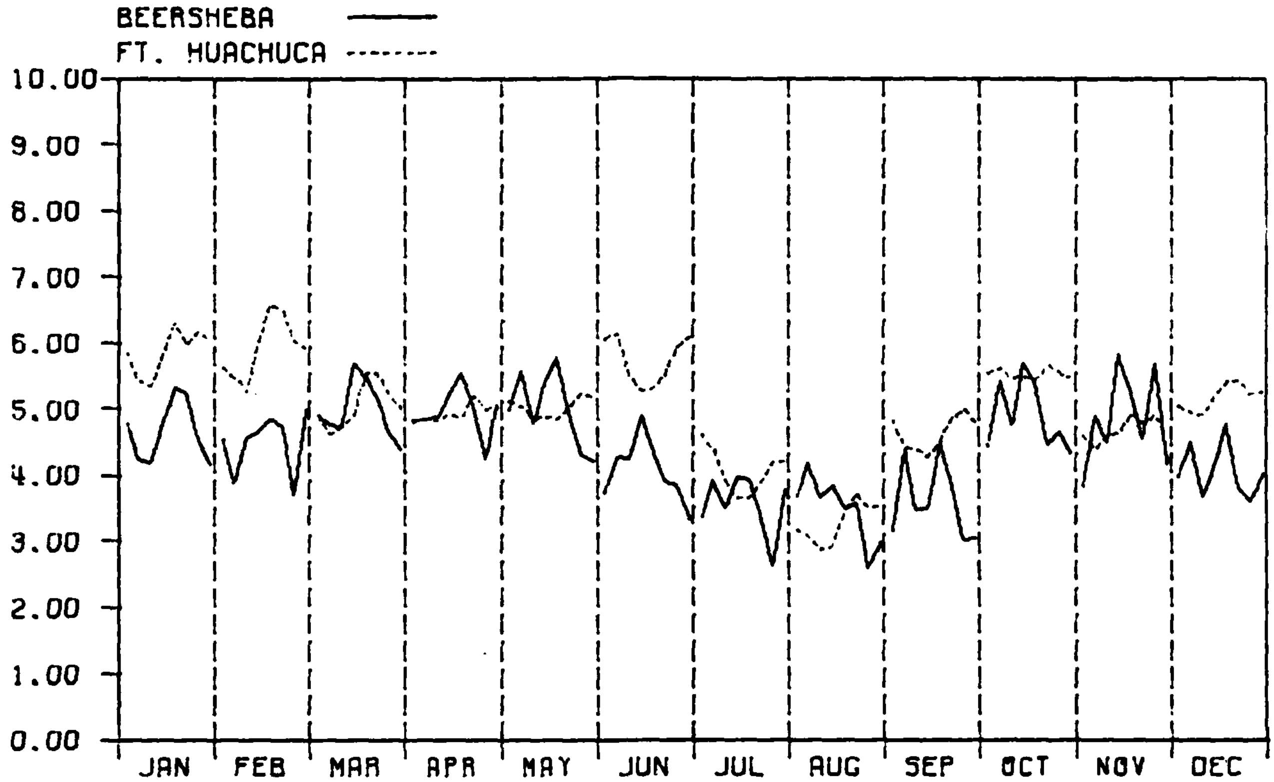


Fig. 32. (Cont'd) DEW POINT TEMP - DEG K
3-HOURLY STANDARD DEVIATIONS. BY MONTH



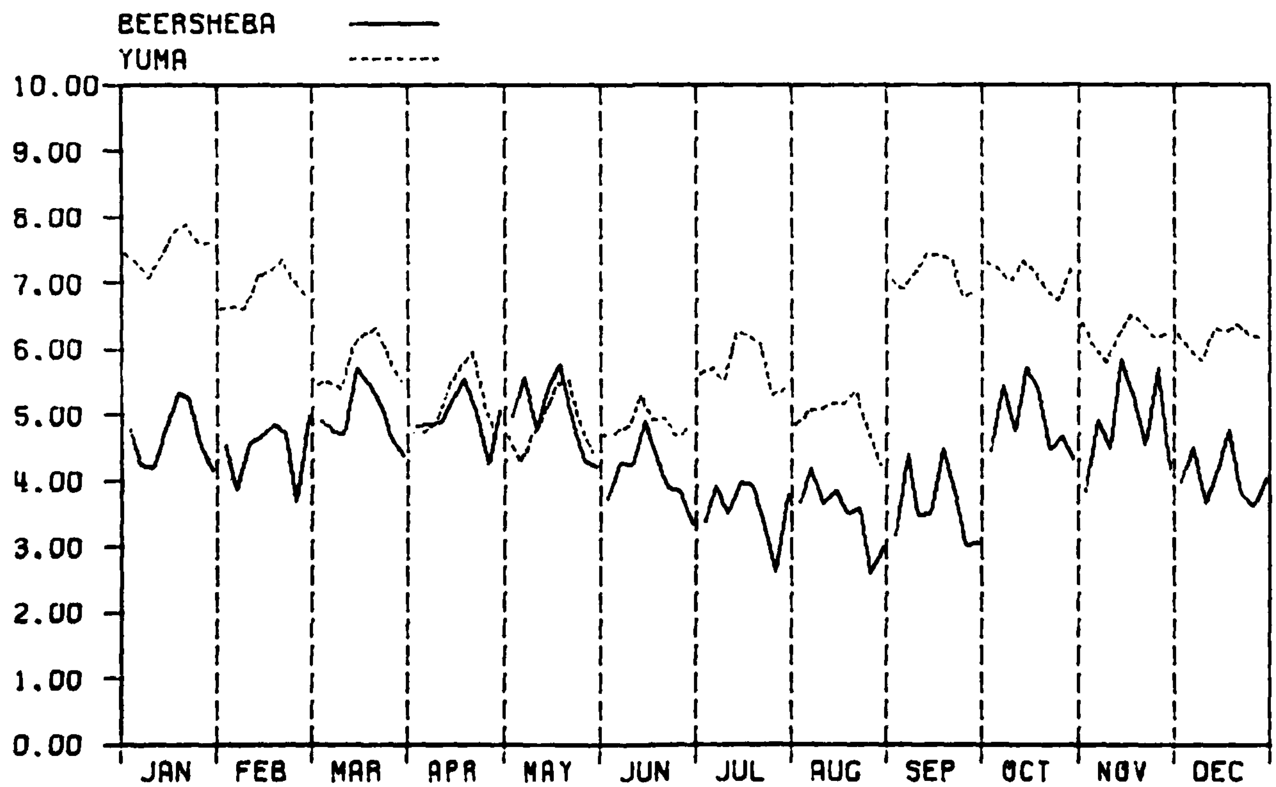
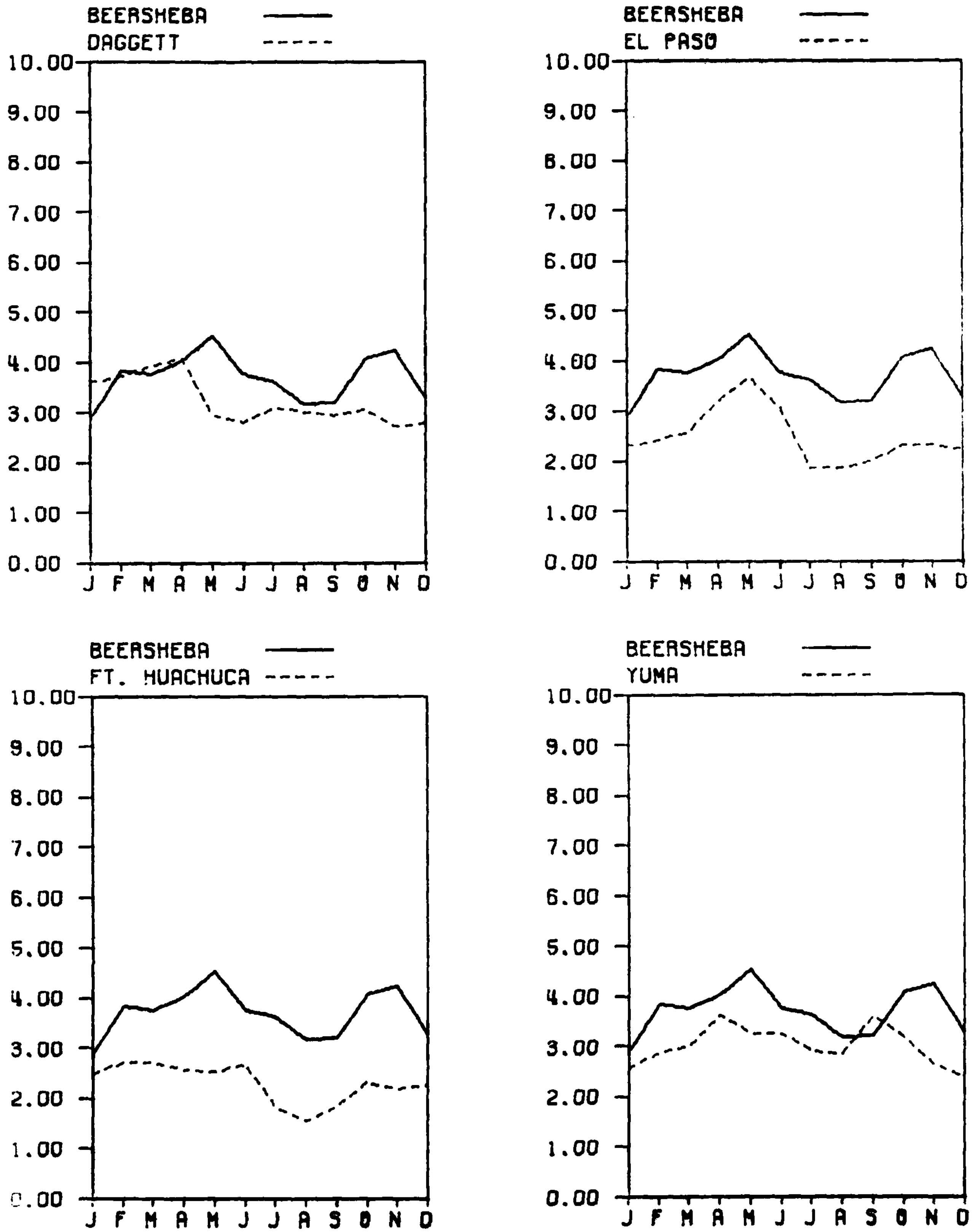



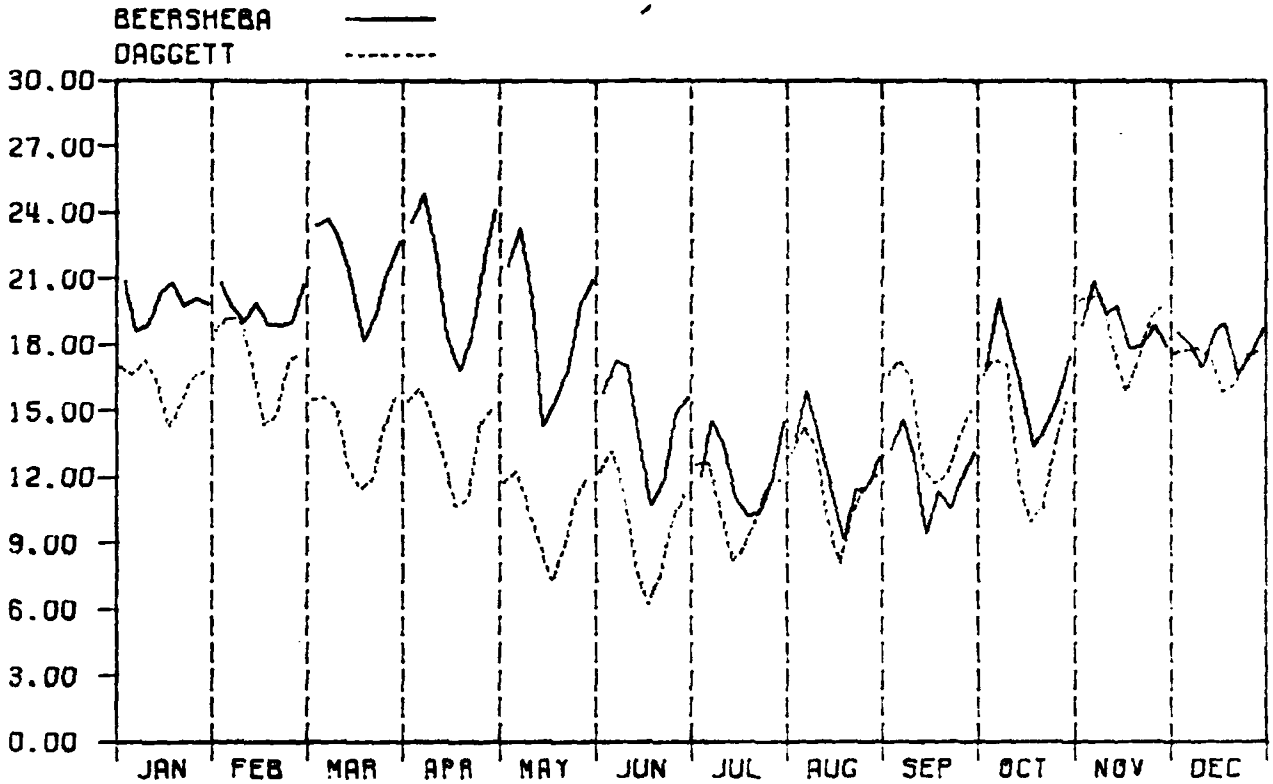
Fig. 33. DEW POINT TEMP - DEG K
DAILY STANDARD DEVIATIONS, BY MONTH



D. Relative Humidity

The 3-hourly and daily standard deviations by month for relative humidity are given in Figs. 34 and 35.

Fig. 34. REL. HUMIDITY - PER CENT
3-HOURLY STANDARD DEVIATIONS. BY MONTH



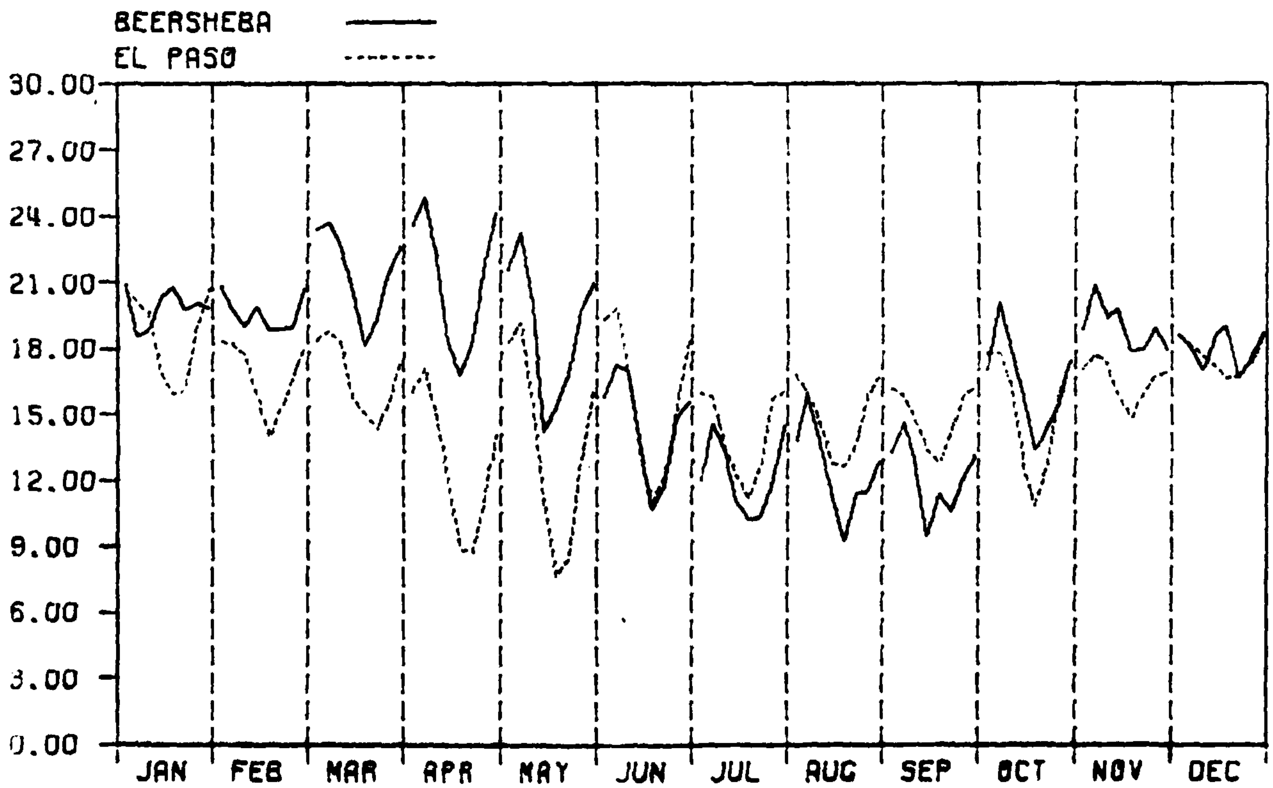
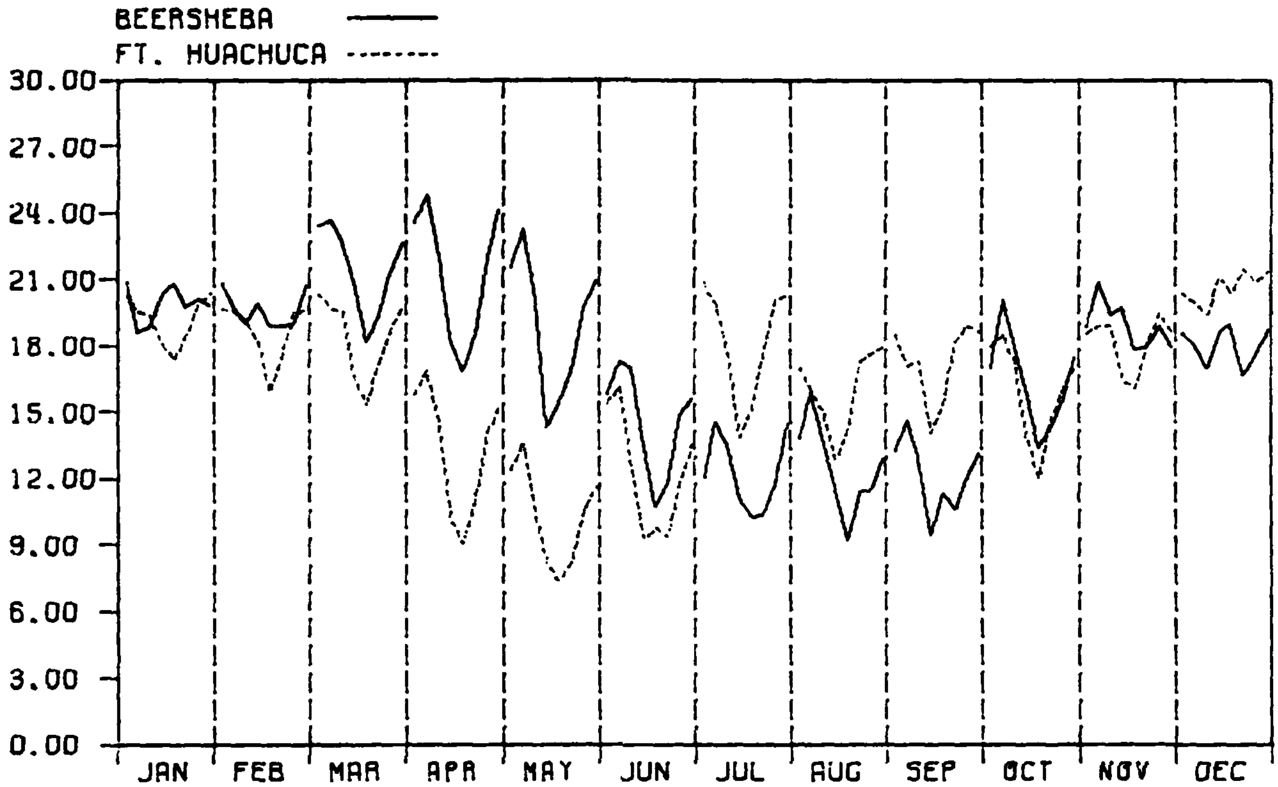



Fig. 34. (Cont'd) REL. HUMIDITY - PER CENT
3-HOURLY STANDARD DEVIATIONS. BY MONTH



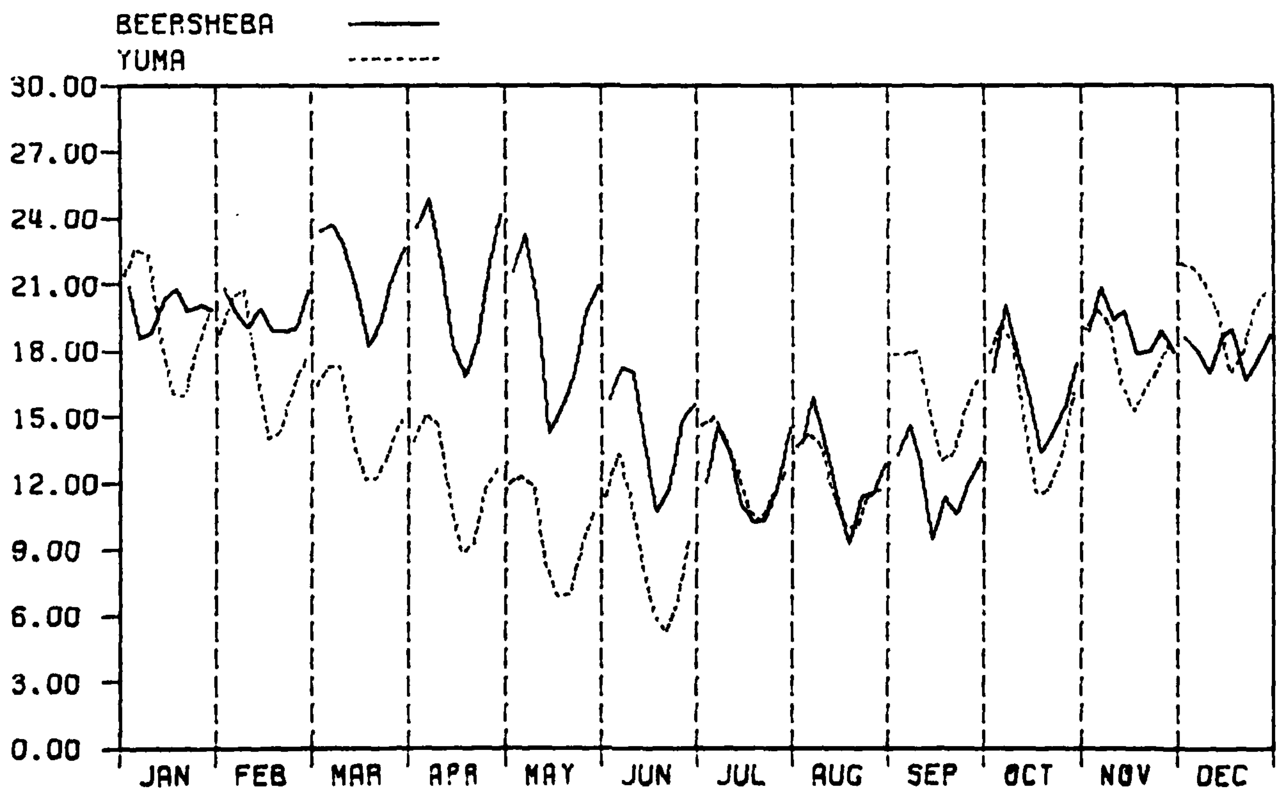
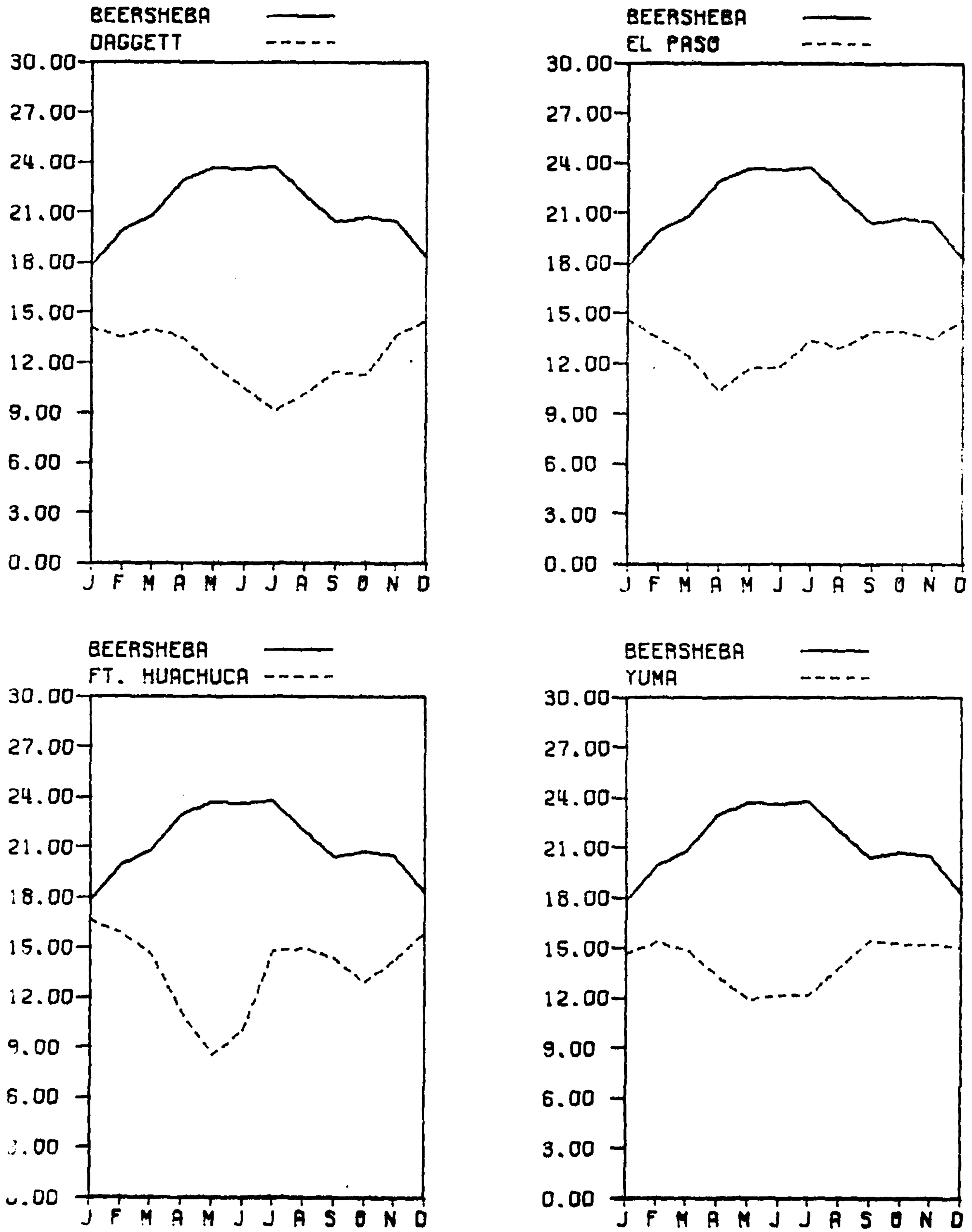



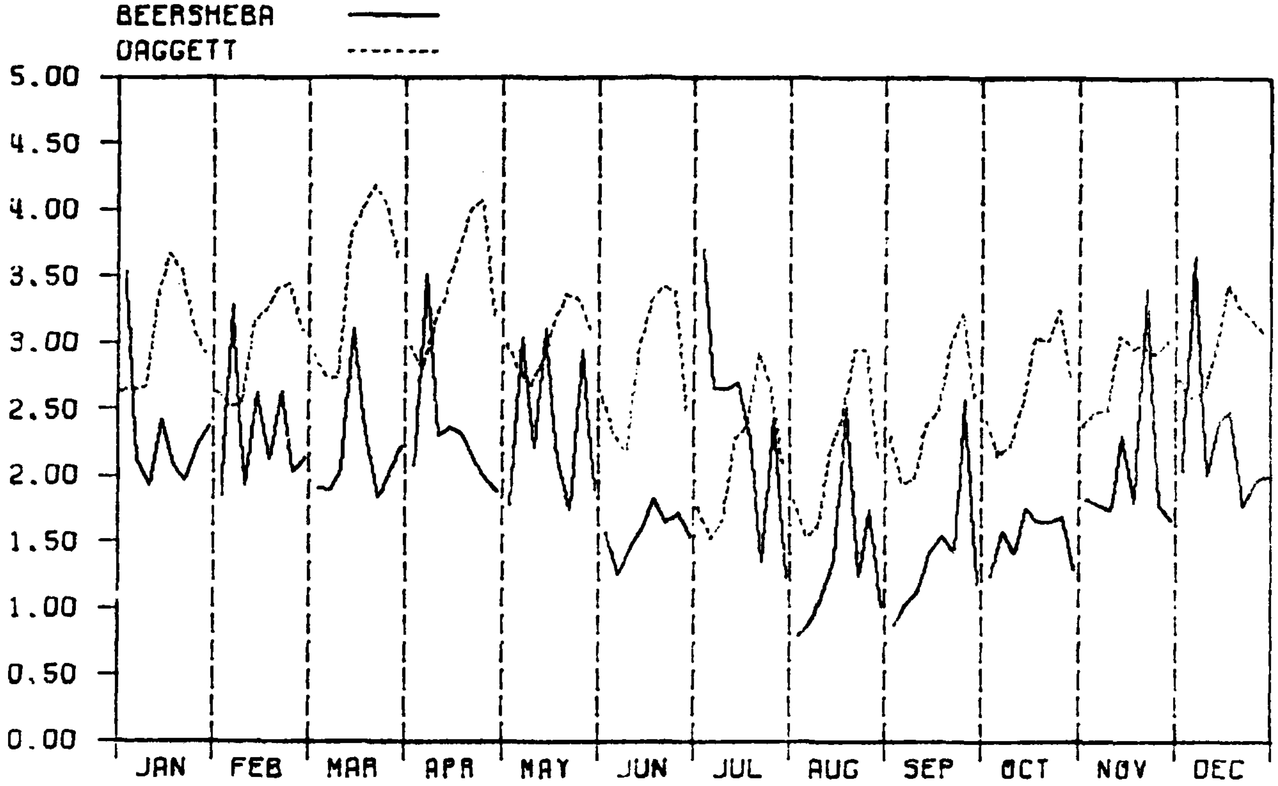
Fig. 35. REL. HUMIDITY - PER CENT
DAILY STANDARD DEVIATIONS, BY MONTH



E. Wind Speed

Figs. 36 and 37 show the 3-hourly and daily standard deviations by month for wind speed.

Fig. 36. WIND SPEED - METERS/SEC
3-HOURLY STANDARD DEVIATIONS. BY MONTH



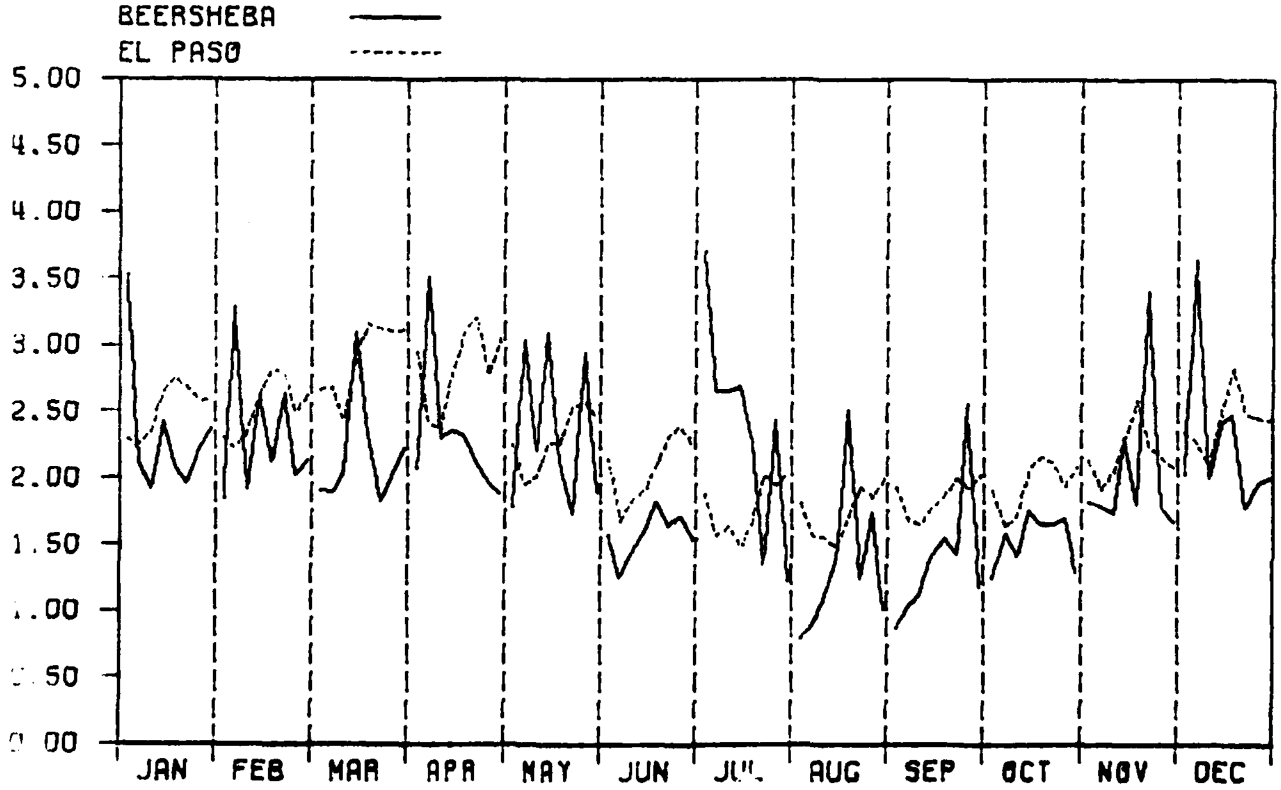
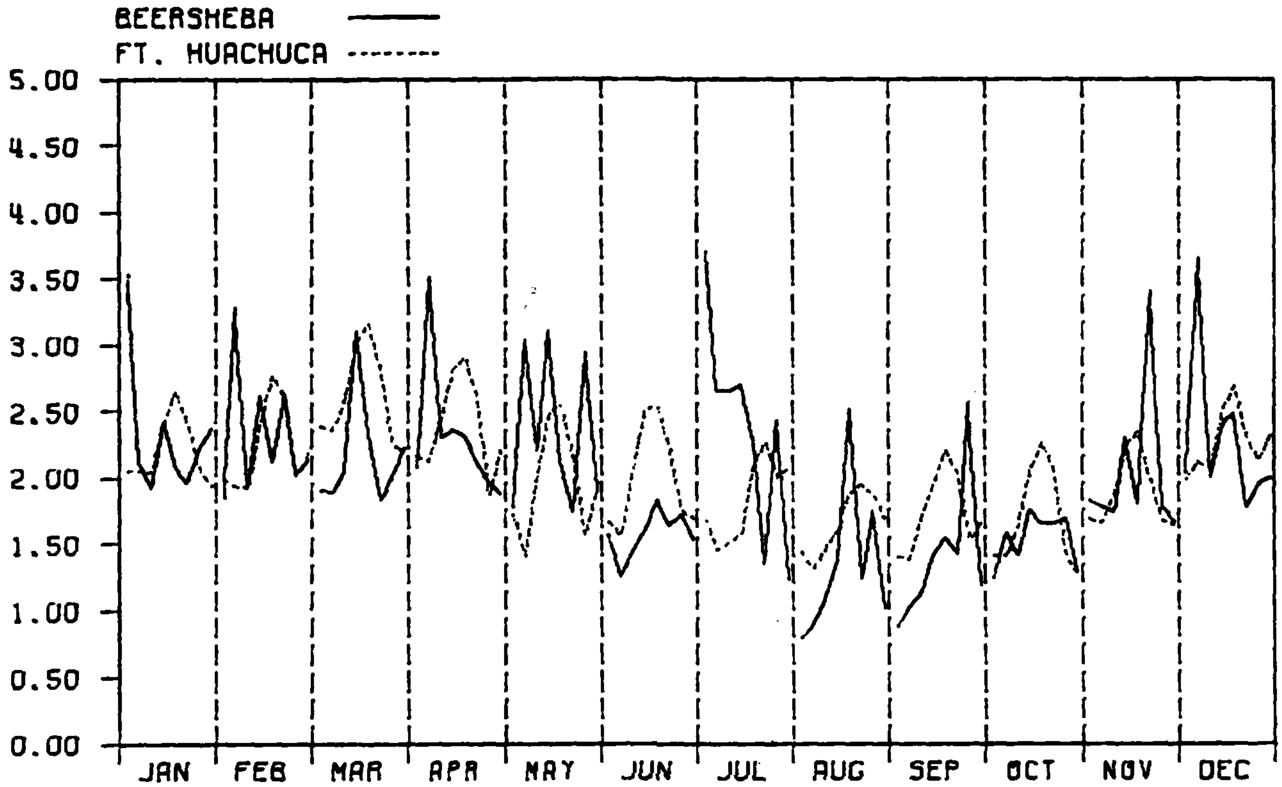



Fig. 36. (Cont'd) WIND SPEED - METERS/SEC
3-HOURLY STANDARD DEVIATIONS. BY MONTH



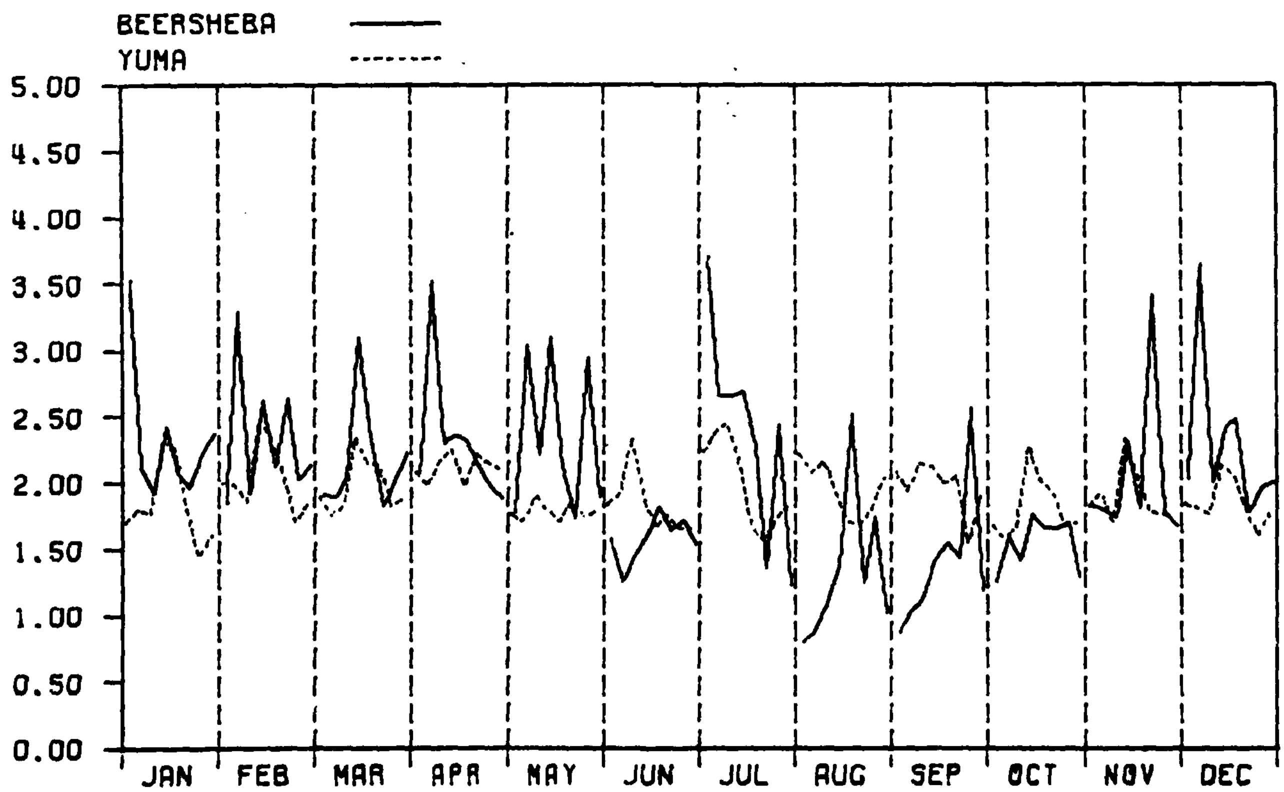
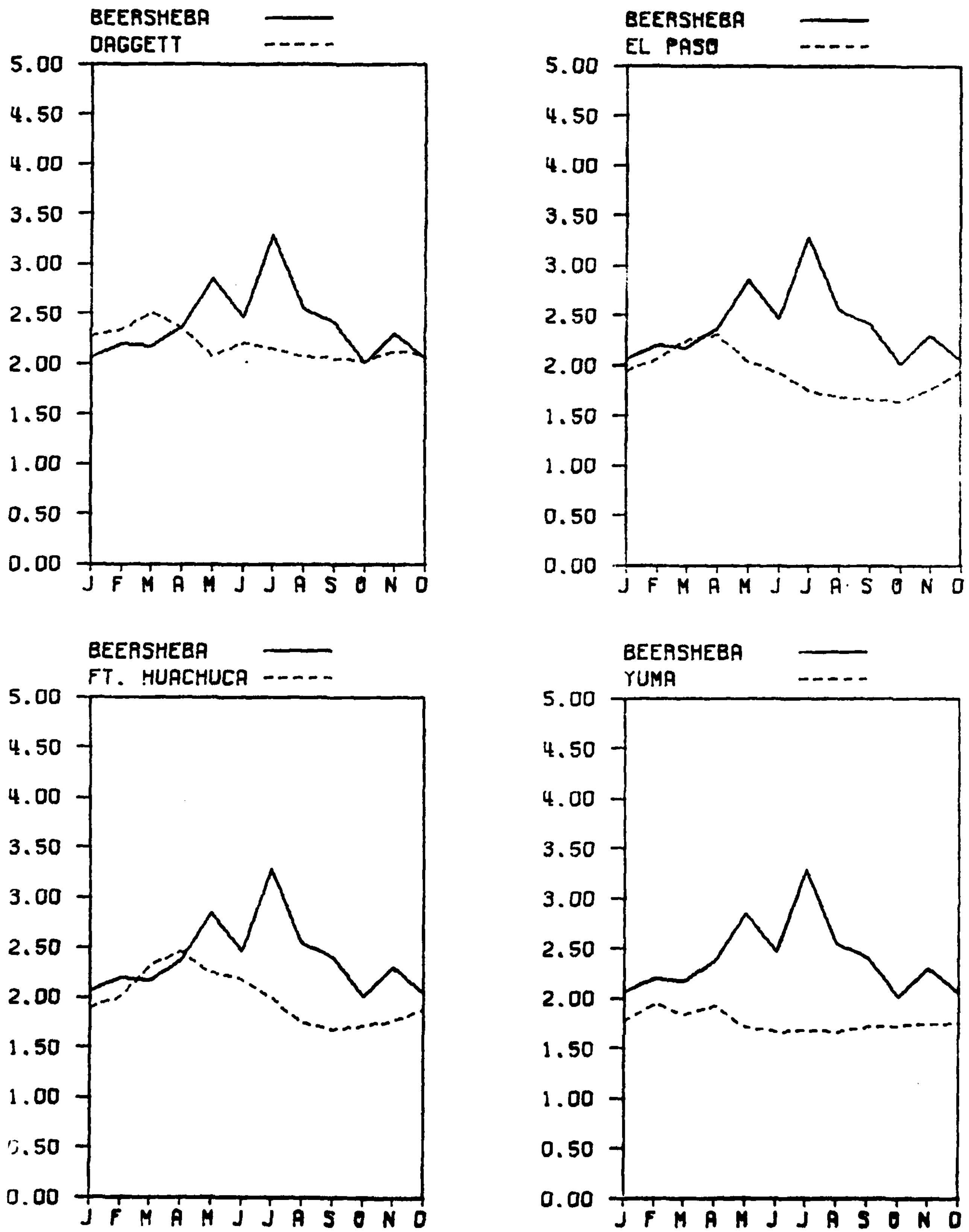



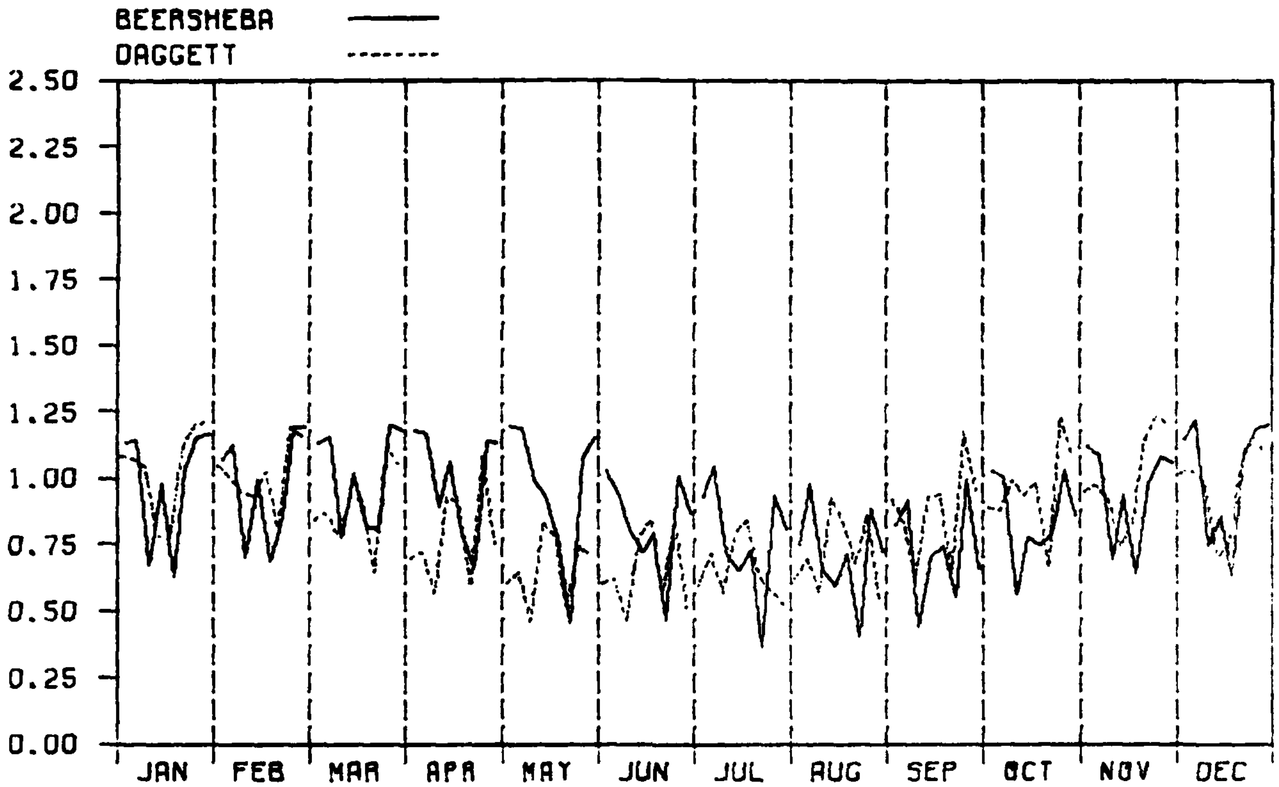
Fig. 37. WIND SPEED - METERS/SEC
DAILY STANDARD DEVIATIONS, BY MONTH



F. Stability Index

The 3-hourly and daily standard deviations for stability are shown in Figs. 38 and 39.

Fig. 38. STABILITY INDEX - 1 TO 7
3-HOURLY STANDARD DEVIATIONS. BY MONTH



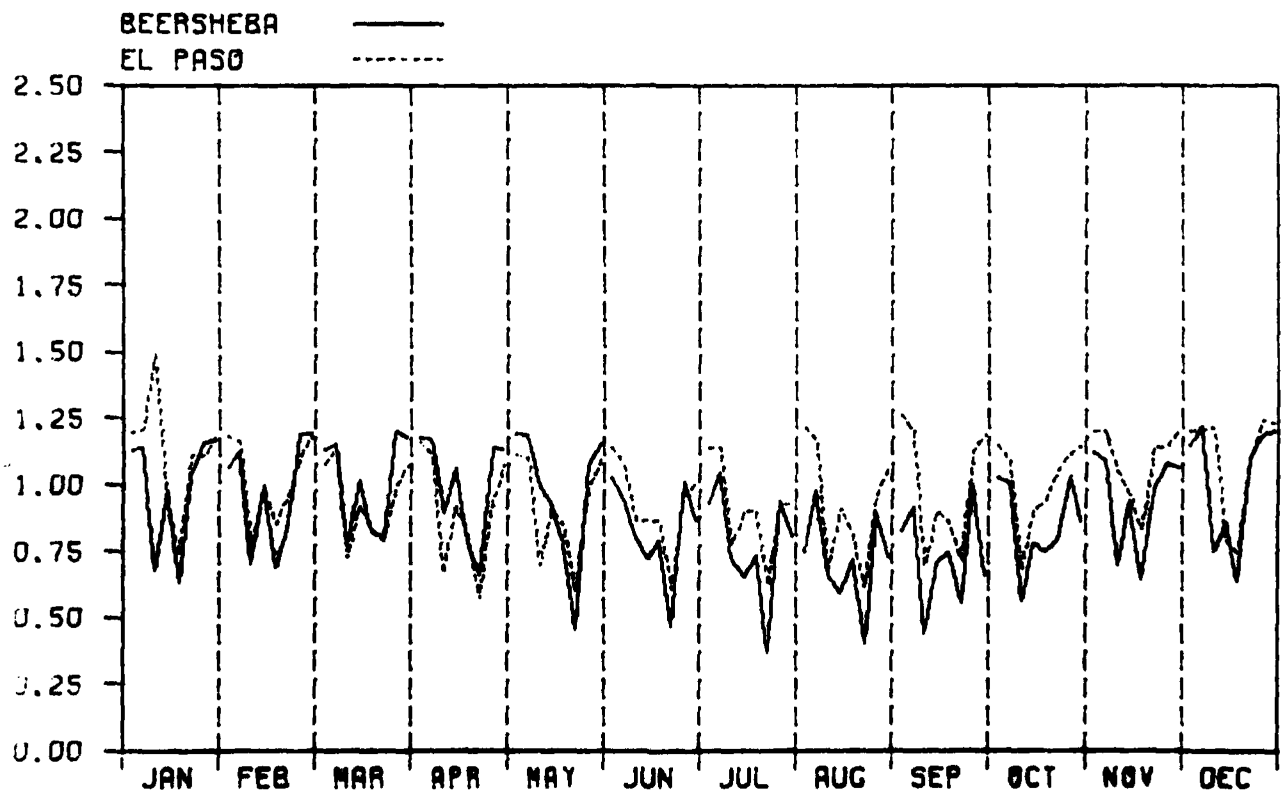
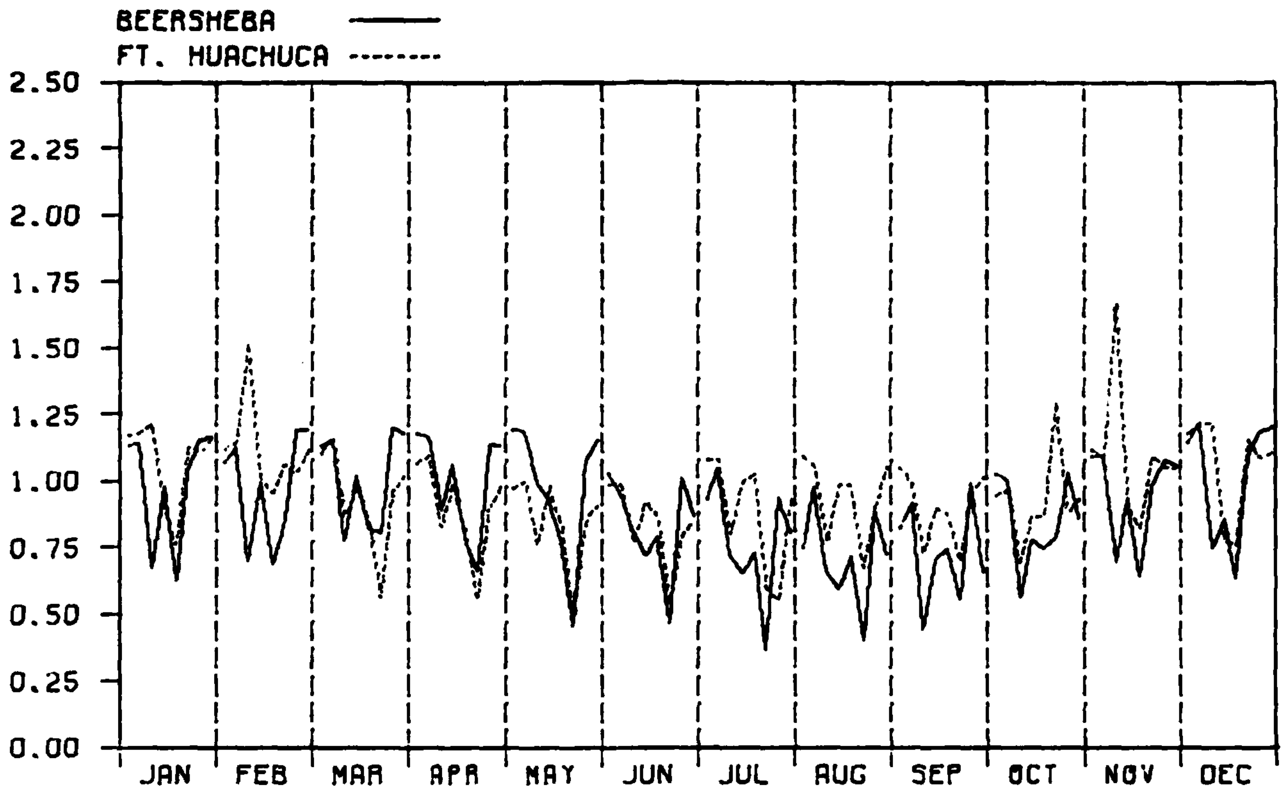



Fig. 38. (Cont'd) STABILITY INDEX - 1 TO 7
3-HOURLY STANDARD DEVIATIONS. BY MONTH



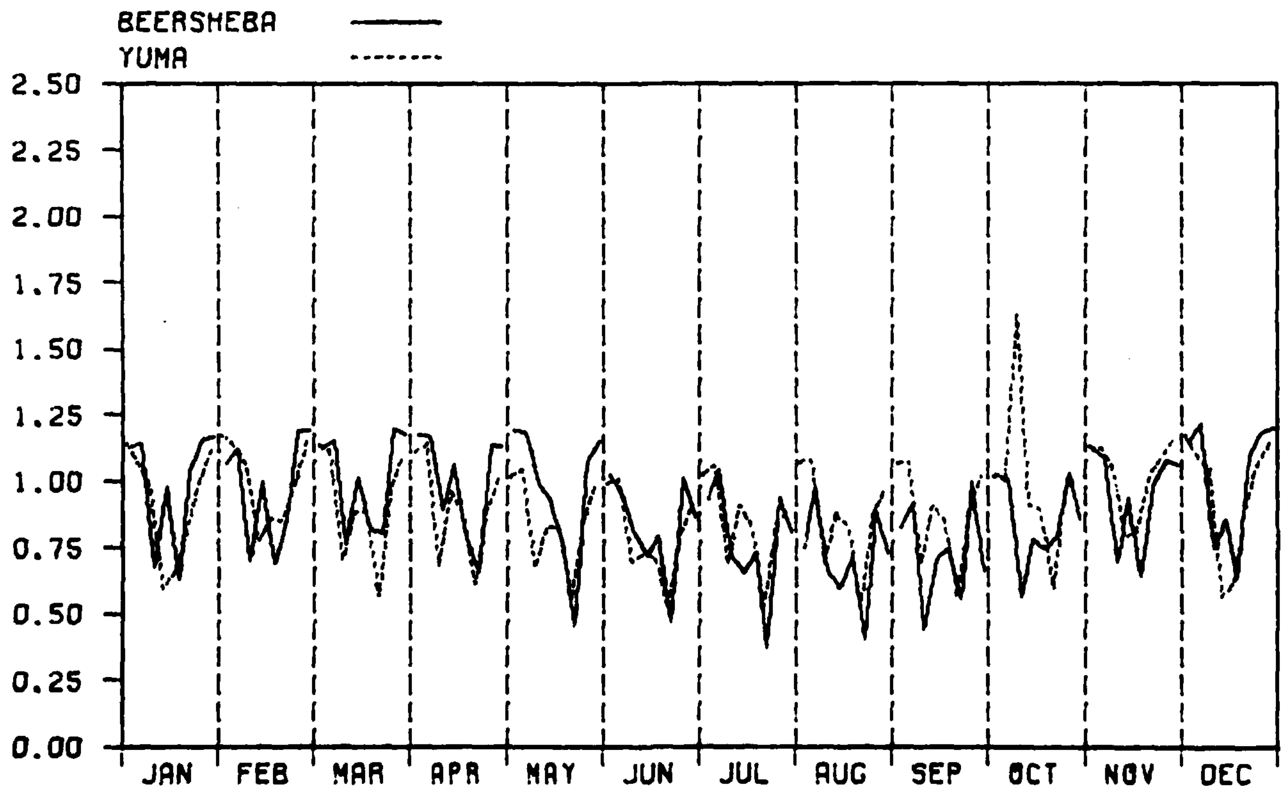
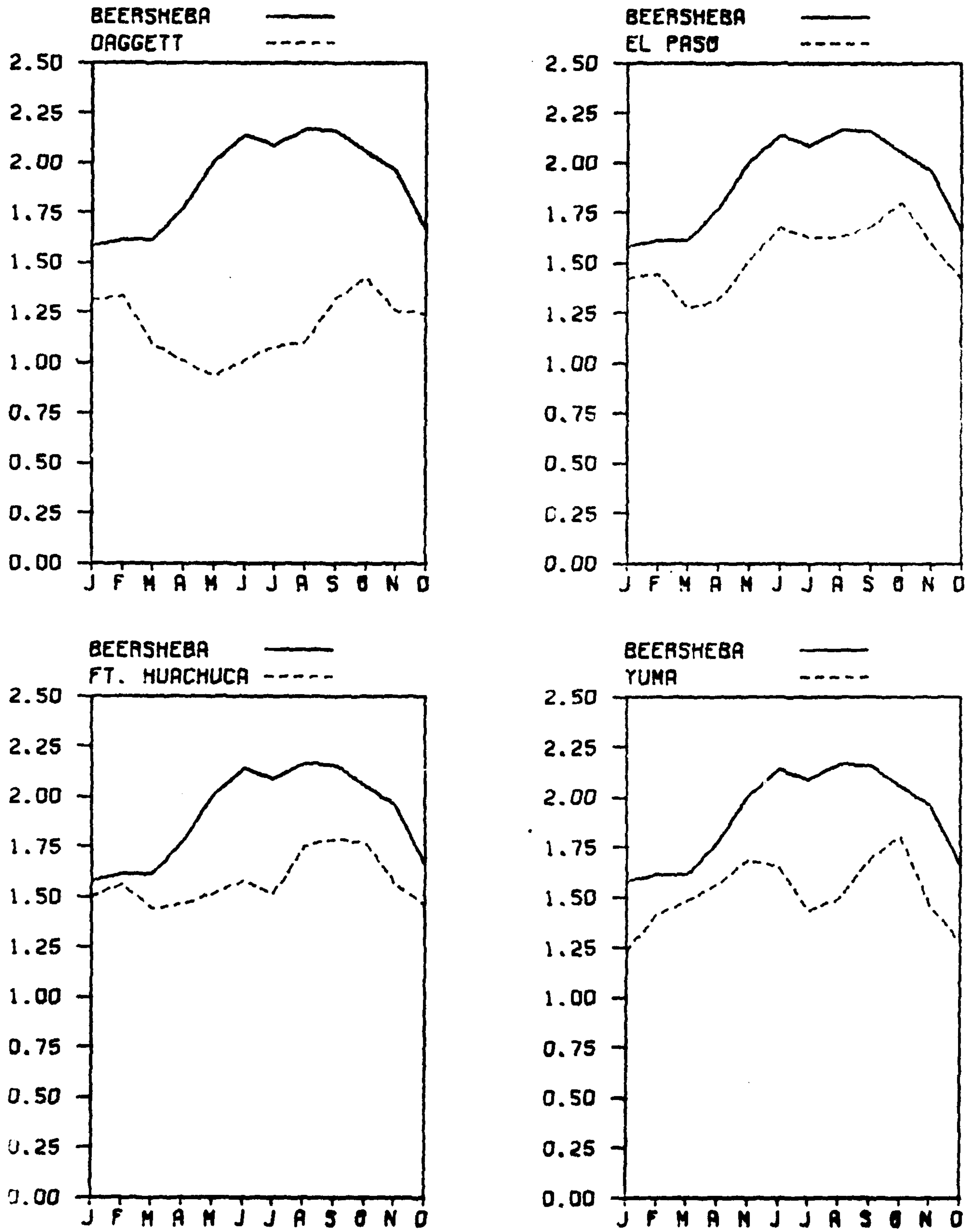



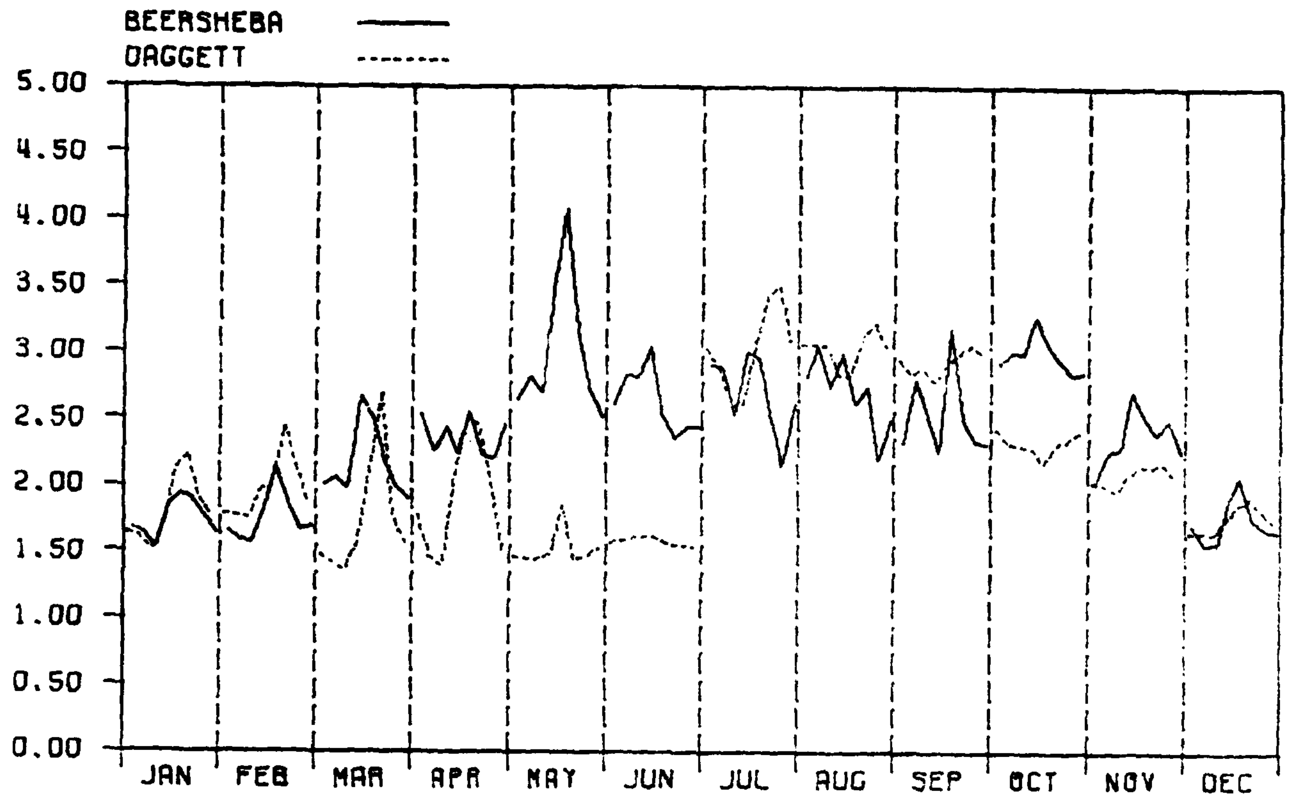
Fig. 39. STABILITY INDEX - 1 TO 7
DAILY STANDARD DEVIATIONS, BY MONTH



## G. Absolute Humidity

Figs. 40 and 41 show the 3-hourly and daily standard deviations for absolute humidity.

Fig. 40. ABS. HUMIDITY - GMS/M3
3-HOURLY STANDARD DEVIATIONS. BY MONTH



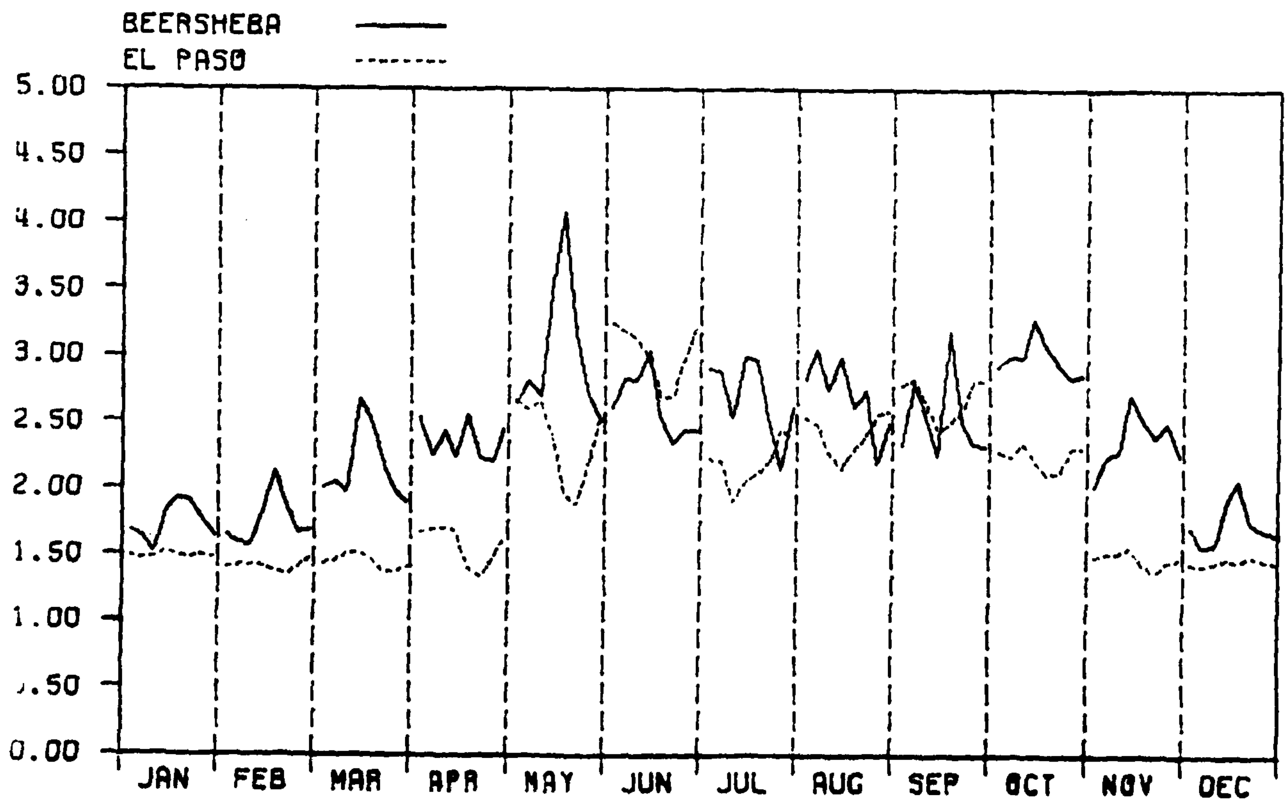
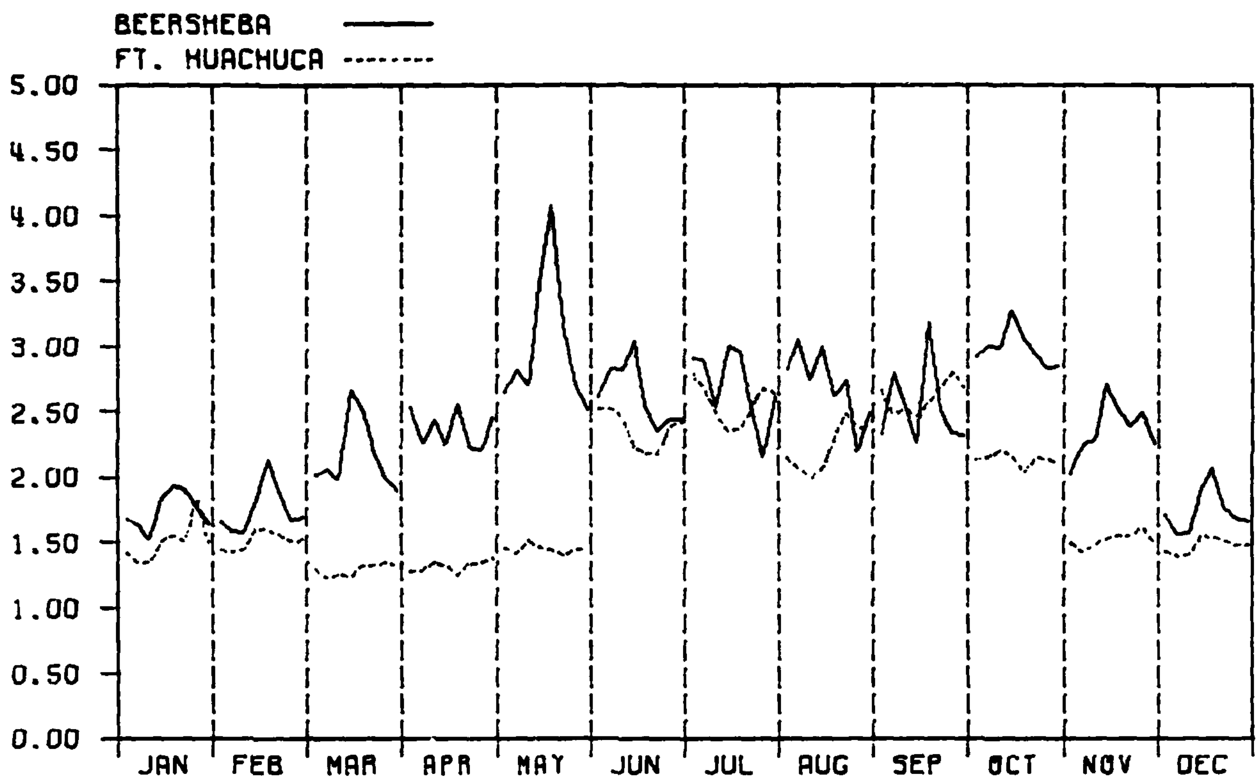



Fig. 40. (Cont'd) ABS. HUMIDITY - GMS/M3
3-HOURLY STANDARD DEVIATIONS. BY MONTH



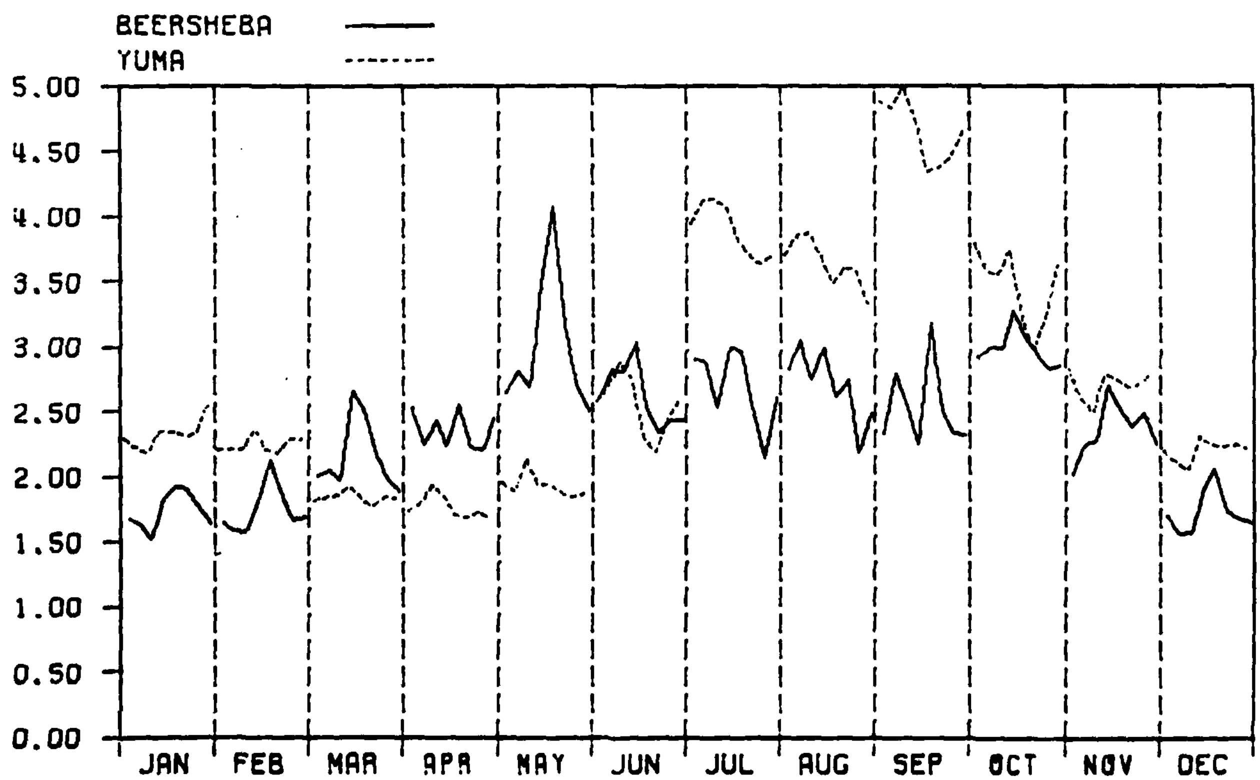
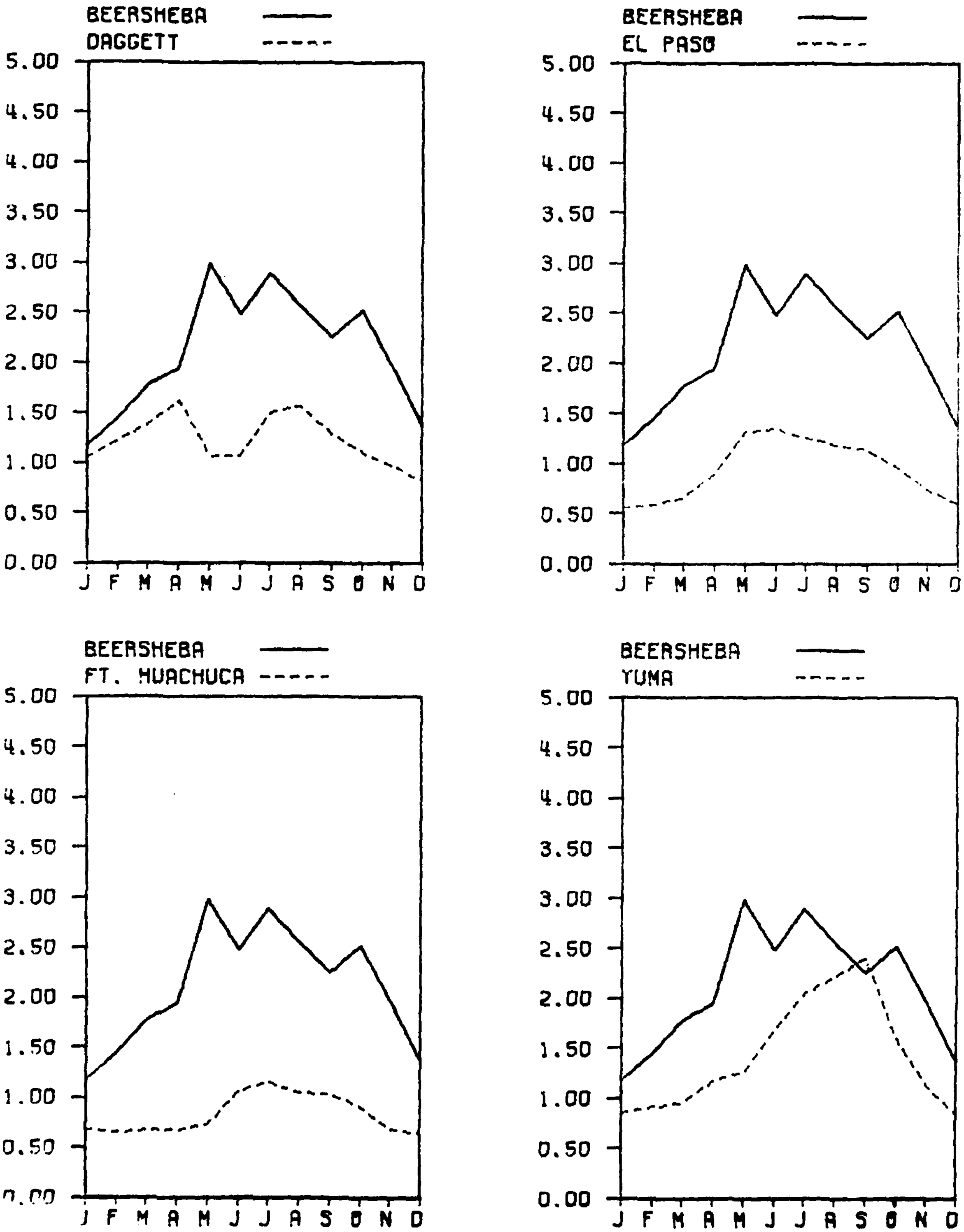



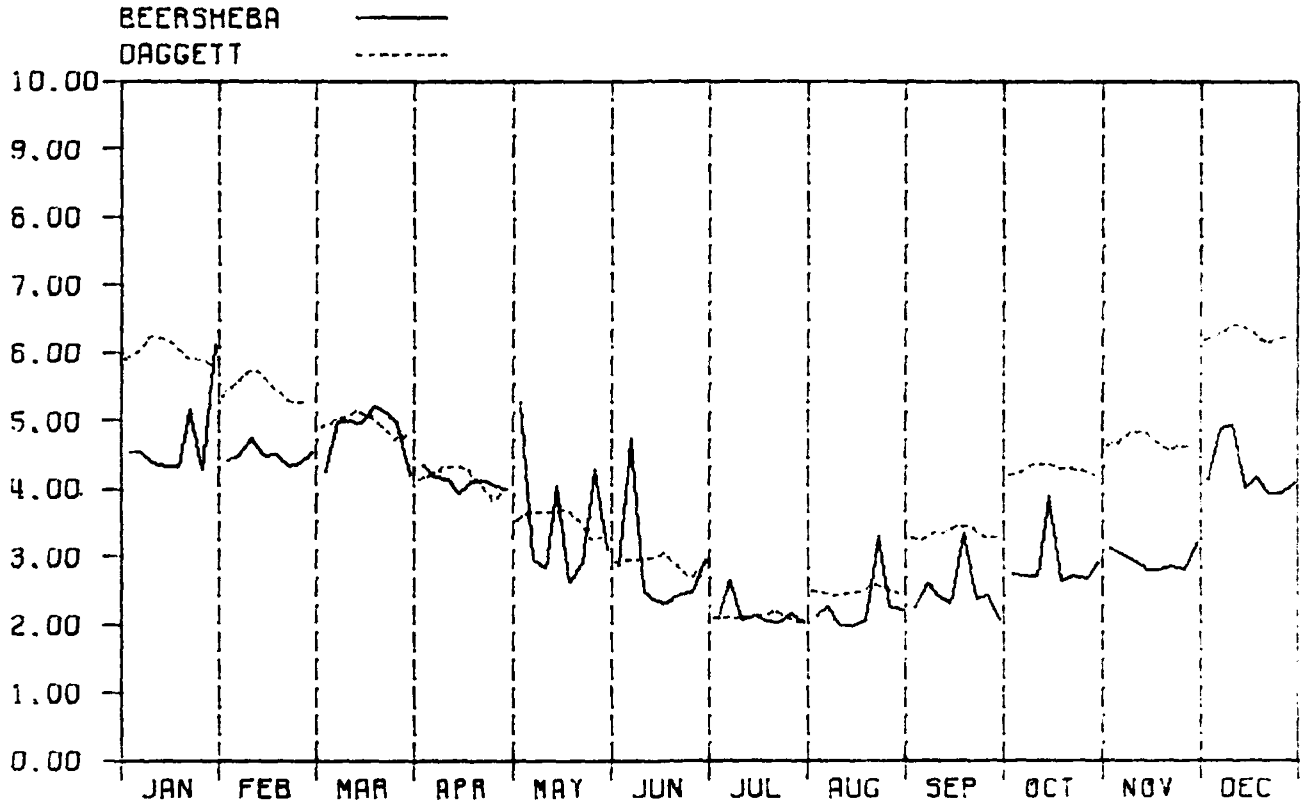
Fig. 41. ABS. HUMIDITY - GMS/M3
DAILY STANDARD DEVIATIONS, BY MONTH

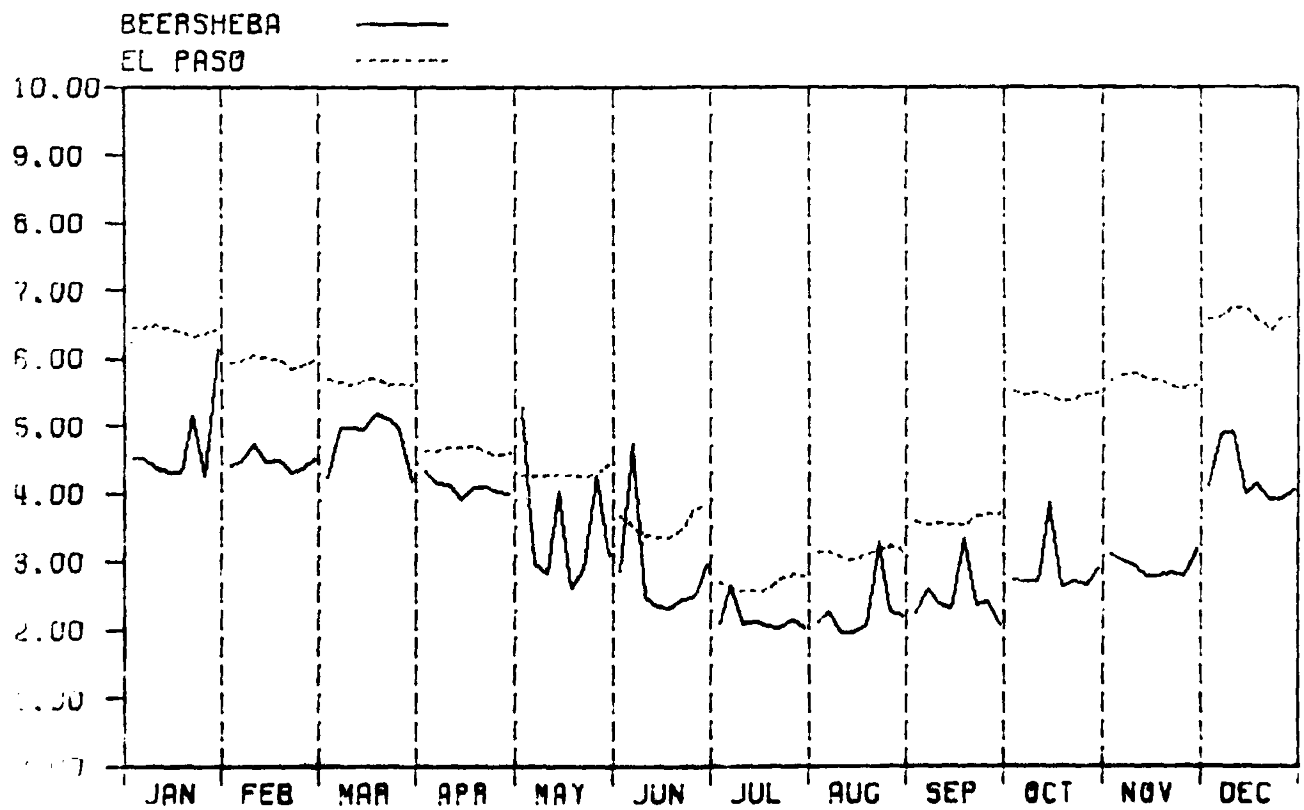


## H. Sea-level Pressure

Figs. 42 and 43 show the 3-hourly and daily standard deviations for sea-level pressure.

Fig. 42. SEA LEVEL PRESSURE - MB
3-HOURLY STANDARD DEVIATIONS. BY MONTH



AD-A097 529 BATTELLE COLUMBUS LABS DURHAM N C F/G 4/2
COMPARISON OF THE CLIMATES OF SELECTED LOCATIONS IN THE UNITED --ETC(U)
JAN 81 C E DUCHON DAAG29-76-D-0100
UNCLASSIFIED ERADCOM/ASL-CR-81-0100-2 NL

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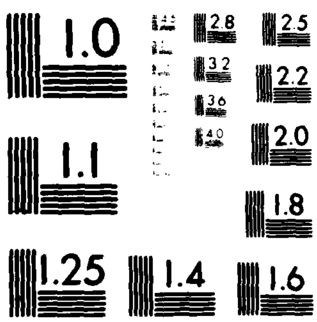


MICROCOPY RESOLUTION TEST CHART

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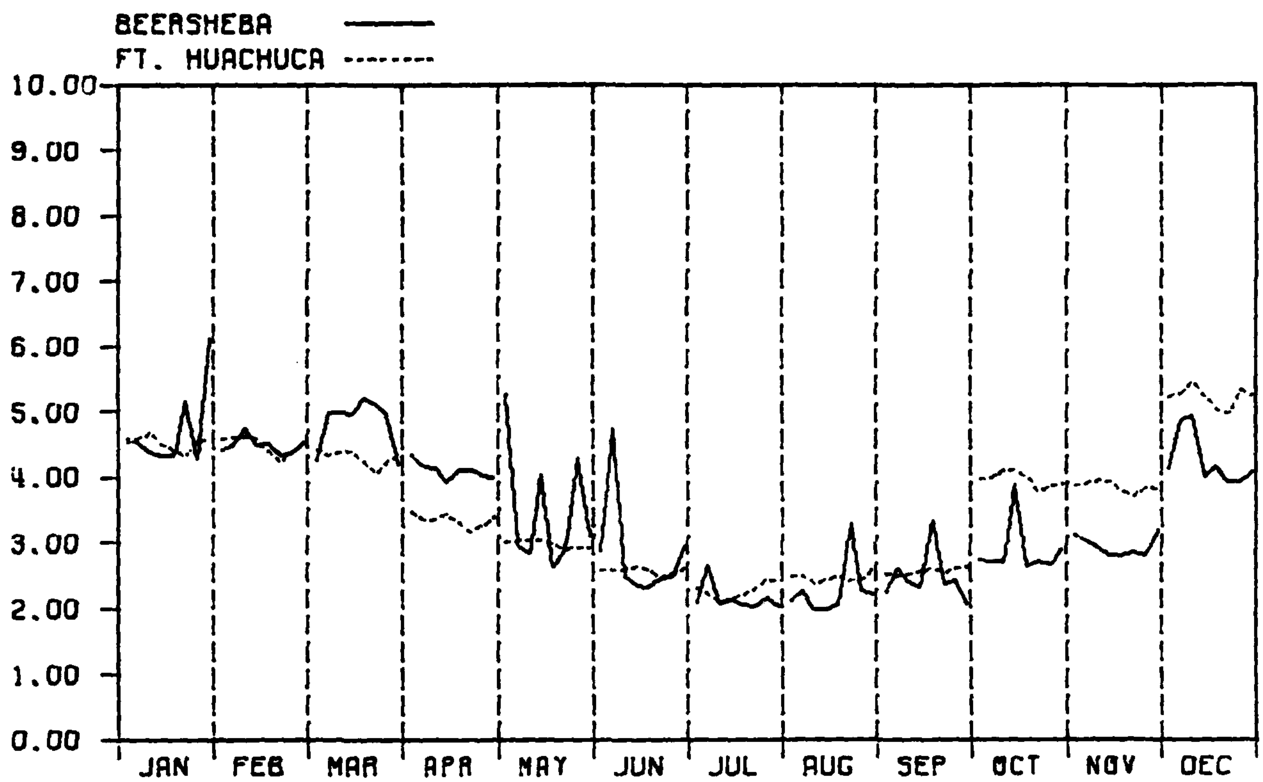
Fig. 42. (Cont'd) SEA LEVEL PRESSURE - MB
3-HOURLY STANDARD DEVIATIONS. BY MONTH



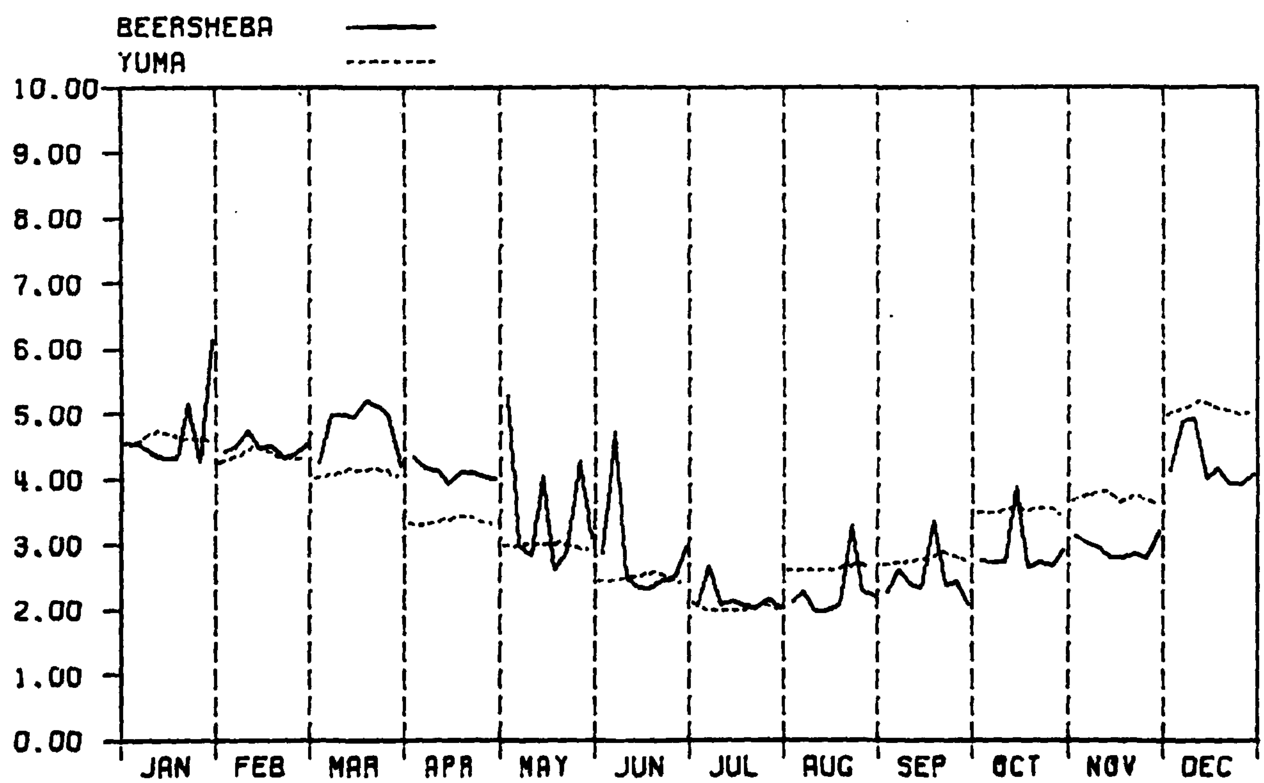
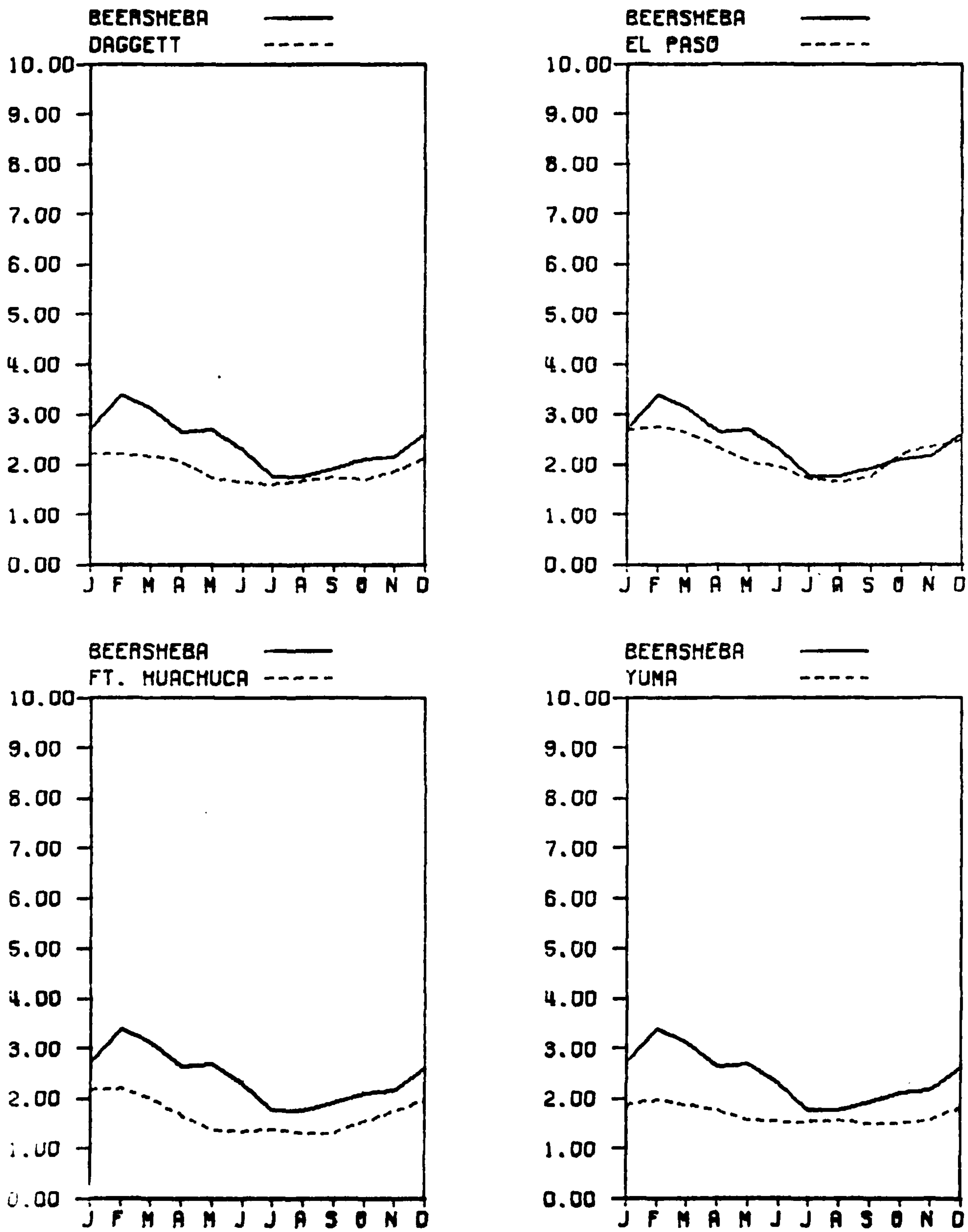



Fig. 43. SEA LEVEL PRESSURE - MB
DAILY STANDARD DEVIATIONS, BY MONTH



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